ECONOMIC IMPACTS OF WATER QUANTITY AND QUALITY CONSTRAINTS ON AGRICULTURE OF THE COLORADO RIVER BASIN

AN INTERINDUSTRY PROJECTIONS STUDY

Natural Resource Economics Division
Economic Research Service
United States Department of Agriculture
Logan, Utah

December 1969

PREFACE

In 1962, the U.S. Economic Research Service entered into a reimbursement agreement with the U.S. Public Health Service that provided for analysis and projections of the agricultural industry in each of six subbasins of the Colorado River Basin. Input-output models were developed for each subbasin. Later, the U.S. Federal Water Pollution Control Administration replaced the Public Health Service as contractor. Several Associated Rocky Mountain Universities, notably the University of New Mexico and the University of Colorado, contracted for the nonagricultural industry portion; representatives of these universities also chaired the Study Advisory Committee.

This report presents analysis and information not available in other reports of the total study. Agricultural and forestry elements of the study also are summarized here. Considerable emphasis is placed in the report on procedures and methodology.

The projections included in this report were transmitted in a report to the Contractor in June 1968. They are used in this report primarily for the purpose of illustrating the method of analysis. Economic Research Service in cooperation with the Office of Business Economics has prepared a more recent set of national and regional projections for official use by Agencies cooperating in comprehensive river basin studies conducted under the auspices of the U.S. Water Resources Council. This latter set of projections includes the Upper and Lower Colorado Water Resource Regions. The two sets of projections differ because of several differences in basic assumptions and because projections for the study reported here were developed for six smaller subbasins rather than for two larger water resource regions covering the Colorado River Basin.

In the initial years. Professor Nathaniel Wollman, University of New Mexico, was Project Leader for the overall study. He was succeeded by Professor William Miernyk, University of Colorado, as leader and in the last year or so of the study, by Professor Bernard Udis, University of Colorado. Clyde E. Stewart, Agricultural Economist, represented Economic Research Service in the Three-Agency Steering Committee for the duration of the study.

Over the study period, several other agricultural economists from Economic Research Service made substantial contributions. These economists included Jay C. Andersen, Paul W. Barkley, M. Glade Pincock, Dean Jansma, and Lynn Wilkes.

Economists of Economic Research Service prepared reports on agricultural and forestry industries for each subbasin in the Colorado River Basin. These reports were incorporated also into a nine volume overall report on the study, edited by Professor Bernard Udis, University of Colorado, and entitled, "An Interindustry Analysis of the Colorado River Basin in 1960 with projections to 1980 and 2010,"

completed June 1968. Details of agricultural as well as nonagricultural features of the subbasins are reported in this larger report. This overall report was processed in relatively few copies so that access and reference to details have to be made through the individuals or universities and agencies involved directly in the study.

Separate subbasin reports for agriculture and forestry are:

1. Stewart, Clyde E. and Lynn W. Wilkes. "An Interindustry Analysis with Emphasis on Water Used by Agriculture and Forestry, Green River Subbasin, Colorado River Basin." Economic Research Service, U.S. Dept. of Agriculture. Logan, Utah. December 1965.

2. Andersen, Jay C. "Agricultural and Forestry Aspects of an Interindustry Analysis of the Upper Main Stem Subbasin of the Colorado River." Economic Research Service, U.S. Dept. of Agriculture. Logan, Utah. September 1965.

3. Wilkes, Lynn W. "Some Economic Features of Agriculture and Forestry in the San Juan Subbasin of the Colorado River Basin." Economic Research Service, U.S. Dept. of Agriculture. Salt Lake City, Utah. August 1966.

4. Wilkes, Lynn W. "An Economic Analysis of Agriculture and Forestry in the Little Colorado River Subbasin, Colorado River Basin." Economic Research Service, U.S. Dept. of Agriculture. Salt Lake City, Utah. September 1966.

5. Jansma, J. Dean. "An Analysis of the Agricultural and Forestry Economy of the Gila Subbasin for 1960 with Projections for 1980 and 2010." Economic Research Service, U.S. Dept. of Agriculture. Salt Lake City, Utah. July 1967. Revised by Lynn Wilkes.

6. Barkley, Paul W. "Some Economic Features of Agriculture and Forestry in the Lower Main Stem Area of the Colorado River." Economic Research Service, U.S. Dept. of Agriculture. Salt Lake City, Utah. February 1968. Revised by Lynn W. Wilkes.

7. Pincock, M. Glade. "Economics of Water Quality in Agriculture - A Case Study - Wellton-Mohawk Irrigation District, Yuma County, Arizona, 1960, 1980 and 2010." Economic Research Service, U.S. Dept. of Agriculture, Salt Lake City, Utah. July 1967.

Close working relations were maintained during the course of the study among participating economists and other personnel from the three agencies. While segments of the investigation were conducted somewhat independently, continued communications were maintained and the total effort was brought together basically in the respective input-output transactions tables that numbered 30 or so in total. This interagency and interdisciplinary relationship was highly successful and a significant feature of this study.

TABLE OF CONTENTS

ECONOMIC IMPACTS OF WATER QUANTITY AND QUALITY CONSTRAINTS ON AGRICULTURE OF THE COLORADO RIVER BASIN AN INTERINDUSTRY PROJECTIONS STUDY

by

Clyde E. Stewart
Agricultural Economist[1/]

A study of the economy of the Colorado River Basin was initiated by U.S. Public Health Service in recognition of a need for an overall analysis of basic industries and relationships and the related projections of economic activity as a framework within which water quality decisions could be made. The input-output interindustry technique was selected because of its comprehensive consideration of economic activity and relationships and because of its manipulative features in considering impacts of alternative resource development and adjustment situations.

In order to facilitate a more adequate analysis, including the need for location of economic activity and adjustments, a small area approach was utilized. Thus, the Colorado River Basin was divided into six subbasins--three Upper Basin and three Lower Basin (figure 1). Separate analyses, models, and projections were developed for each subbasin. Water quantity and quality and other constraints and opportunities were considered for each subbasin. This approach increased the requirements for additional and more accurate data. These data were only partly available from secondary sources so that special surveys and contacts were necessary.

A major purpose and use of this study has been its extension by the Federal Water Pollution Control Administration in appraisal of damages from various pollution sources and of the value of various remedial and adjustment programs. This study is an effort to utilize the input-output interindustry technique in projections of small area economies. As will be noted later, attempts were made to avoid the usual objectionable assumptions to this technique.

The economic, physical, and legal framework of use and development of water in the Colorado River Basin and the analysis of water quantity and quality constraints dictate reasonably close location of resource use. As a minimum, the six subbasins seemed an essential delineation. For some analytical purposes it was essential to locate the water resource even more specifically within each subbasin.

WATER QUALITY PROBLEM IN AGRICULTURE

In the Colorado River Basin, agriculture is heavily involved in both receiving and contributing aspects of water quality deterioration. As

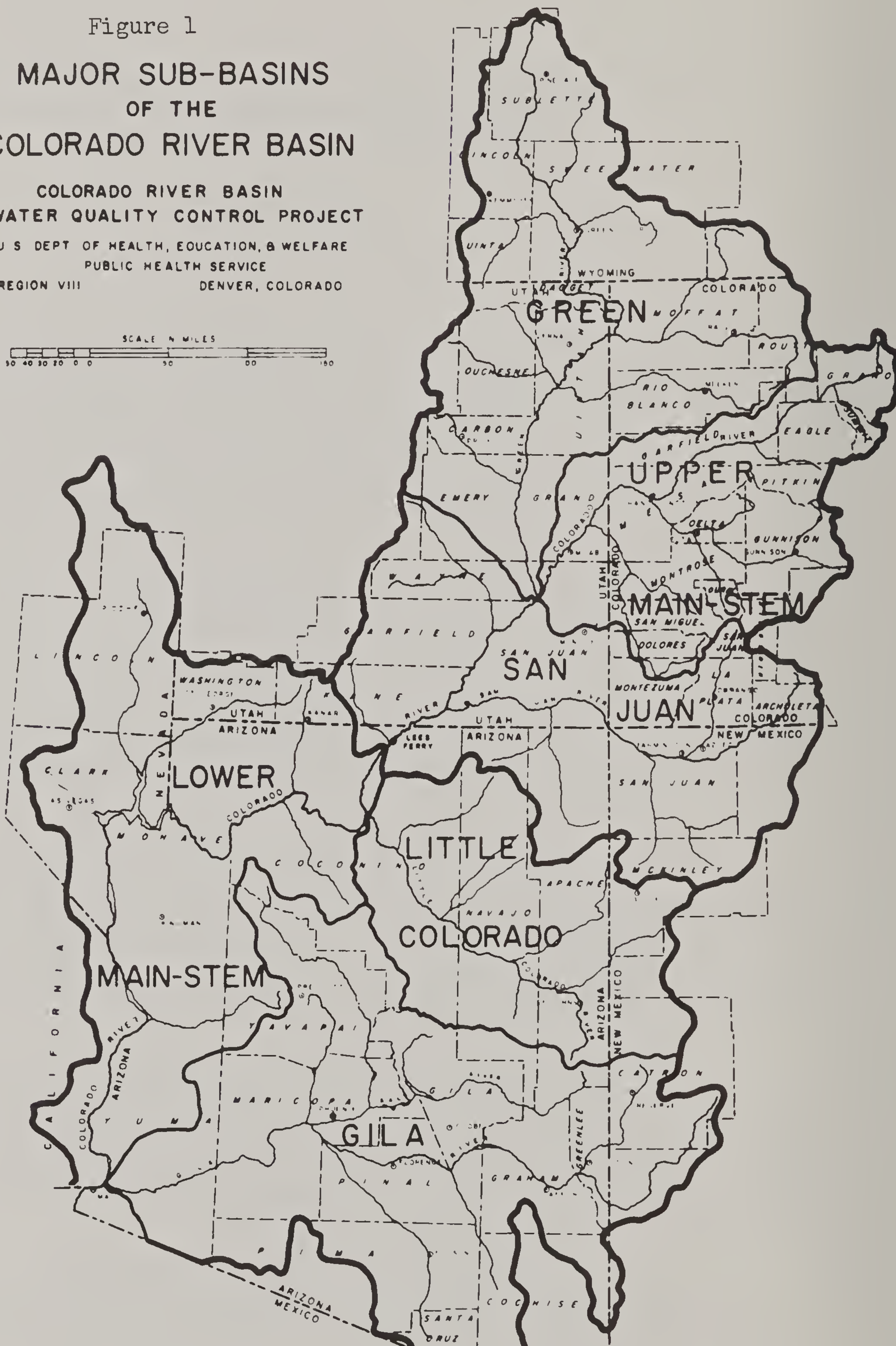
1/ Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture, Logan, Utah.

Figure 1

MAJOR SUB-BASINS
OF THE
COLORADO RIVER BASIN

COLORADO RIVER BASIN
WATER QUALITY CONTROL PROJECT

U S DEPT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO



water proceeds downstream, it frequently becomes poorer in quality through addition of pollutants or through larger concentrations of pollutants because of diminished water quantities. These deteriorated supplies of water as diverted for irrigation have significant impacts on farm incomes and costs. They also add substantially to water costs for domestic and industrial uses.

In this process of diversions, use, return flows and natural surface runoff, agriculture contributes along with other sources to pollution of water supplies. Agricultural pollutants include salts, plant nutrients, sediment, organic materials, herbicides, pesticides, and other materials detrimental to use and re-use of the water.

Increased salinity from irrigation return flows appears to be the major pollutant from agricultural production in the Basin, especially as related to specific actions and practices by farm operators. Natural runoff in contrast with irrigation and return flows is somewhat outside the control of farm operators, although certain farm practices and inputs can influence natural runoff of water.

The unique and extremely difficult economic problems related to irrigation return flows involve "external" economies and diseconomies. These problems occur with both quantity and quality of water. The problem concerns two or more areas of firms or groups of firms that are interdependent in the physical use of resources but that make decisions independently.

These "external" economic problems frequently are referenced in terms of incidence of costs and benefits or incomes. Or they can be expressed as cases of disassociation of benefits and costs.

In the case of irrigation return flows, two major physical events usually occur: (1) A portion of the original water supply is re-used (re-applied) for irrigation one or more times because irrigation does not involve a 100 percent disappearance of applied water, and (2) re-used water in a smaller quantity is usually of poorer quality than the original supply.

The re-use of water has important implications from the standpoint of total supply and efficiency of use. A given storage supply development may effectively provide substantially more acre feet of water in terms of applied usage for irrigation than is suggested by the reservoir capacity and project size. This re-use has significant effects on value of the project and on financial feasibility and incomes of the project area. This feature of irrigated agriculture appears not to have been completely recognized in project formulation.

A major hypothesis is that the re-use of water through return flows shifts the costs of water quality deterioration from the upstream to the downstream users. An upstream user applies water and makes decisions without regard to costs of waste disposal (irrigation, livestock, pesticides, herbicides); thus, he tends to overproduce in terms of economic

criteria since his costs are understated. In turn, the downstream use is affected by the quality deterioration from upstream; his costs are overstated, and he produces at less than economically advisable otherwise. The external diseconomies of this production process transfer costs of water quality deterioration from one unit or area to another by a technical or physical linkage between the production processes.

The market and price system does not reflect these conditions of external diseconomies or adjust for these economic inefficiencies or incidences of costs and benefits. Arrangements outside the regular market operations are likely necessary to accomplish improved efficiencies and otherwise to alleviate problems associated with water quality deterioration.

DATA SOURCES

Numerous sources of data were used for this analysis. Control totals for the base year 1960 came from published sources supplemented by unpublished information and informed judgments.

Special field surveys were not made for the agricultural sectors, although some supplemental surveys would have been highly useful; time was not available. Farmer interviews and farm budgeting done earlier at Experiment Stations and by the U.S. Department of Agriculture were utilized heavily. Key individuals were contacted in the respective areas for specialized information. The U.S. Forest Service, the Bureau of Land Management, and State land administering agencies supplied base data and projections on forests and grazing.

Economic data are published largely by political subdivisions, primarily county, state and national. To accommodate this situation, a "representative" county concept was utilized in this study. Thus, while the subbasins in figure 1 are delineated by hydrologic boundaries, economic activity for the respective subbasins is a grouping of counties that correspond as nearly as possible to hydrologic areas (table 1). In most instances, acreages in the economic analysis exceed acreages in hydrologic areas but total economic activity for the various hydrologic areas coincides rather closely with the respective county groupings.

INPUT-OUTPUT MODELS

Traditional input-output models were developed for each subbasin. These models are comprised of the major producing and processing sectors and industries and of final demand and final payments.

Equality of rows and columns in dollar amounts apply only to the processing sectors. Final demand and final payments which are not industries in the usual sense account fully for disposition of total outputs and inputs not included in the processing section of the model. Aggregate final demand does equal aggregate final payments. These notes will be relevant for summaries and presentations later in this report.

Table 1.--Representative counties of the Colorado River Basin, by subbasins and states

Subbasin	State and County
I. Green	Colorado 1. Moffat 2. Rio Blanco 3. Routt
	Utah 1. Carbon 2. Daggett 3. Duchesne 4. Emery 5. Uintah
	Wyoming 1. Lincoln 2. Sublette 3. Sweetwater 4. Uinta
II. Upper Main Stem	Colorado 1. Delta 2. Dolores 3. Eagle 4. Garfield 5. Grand 6. Gunnison 7. Hinsdale 8. Mesa 9. Montrose 10. Ouray 11. Pitkin 12. San Miguel 13. Summit
	Utah 1. Grand
III. San Juan	Colorado 1. Archuleta 2. La Plata 3. Montezuma 4. San Juan
	New Mexico 1. San Juan
III. San Juan (cont'd.)	Utah 1. Garfield 2. Kane 3. San Juan 4. Wayne
IV. Little Colorado	Arizona 1. Apache 2. Navajo
	New Mexico 1. McKinley
V. Gila	Arizona 1. Cochise 2. Gila 3. Graham 4. Greenlee 5. Maricopa 6. Pima 7. Pinal 8. Santa Cruz 9. Yavapai
	New Mexico 1. Catron 2. Grant
VI. Lower Main Stem	Arizona 1. Coconino 2. Mohave 3. Yuma
	Nevada 1. Clark 2. Lincoln
	Utah 1. Washington

As many as 36 processing sectors were used in the subbasin models. The largest number occurred in the Gila Subbasin (table 2). The fewest processing sectors (22) occurred in Green Subbasin largely because agriculture was treated as a single sector. All subbasin models utilized eight final demand and final payment sectors (table 2).

From procedural and realistic standpoints, agricultural sectors are not defined or structured the same in all instances among subbasins. Reference has been made to the situation in Green Subbasin. Other major notable differences are: (1) range livestock and dairy sectors in Upper Main Stem and San Juan Subbasins include forage and other crop production associated with ranch and dairy operations; land and its production are excluded from these sectors in the lower subbasins, and (2) forage, feed and food sector differs as noted in item (1), plus the occurrence in the upper subbasins of relatively large acreages of dryland crops, mainly wheat and beans; virtually all cropland in the lower subbasins is irrigated.

While control totals by industries pose a data problem, the major analytical and data problem is establishing relationships and allocating total output to various purchasing and producing sectors and to final demand and final payments sectors. Imports and exports constitute one of the more difficult as well as important elements in this allocation; these magnitudes are especially difficult to determine in small area studies because of the sparsity of data on trade movements of inputs and outputs. In this study, movements both between subbasins and outside the Colorado River Basin were estimated.

The study does not provide for estimates of incomes and coefficients for the total Colorado River Basin or for Upper and Lower Basins. The objectives of the study led to concentration on the smaller subbasin delineations and development of I-O models for these subdivisions of the Basin.

ECONOMIC PROJECTIONS

The base year selected for the study is 1960. Projections were made for 1980 and 2010. Prices for the projections years were maintained at the 1960 level. The general procedure was to (1) establish input-output models for six subbasins for the base year 1960, (2) develop similar projected models for 1980 and 2010 "unconstrained" by water quantity or quality, (3) impose water quantity constraints on each projected economy, and (4) impose water quality constraints on the models resulting in step (3).

Because of the heavy resource orientation of the agricultural industry, some water quantity constraints were, in fact, applied in the so-called "unconstrained" projections stage. For example, land development and crop production were not extended beyond the apparent general physical availability of water for irrigation even though large acreages of undeveloped land suitable for crop production are available in the Basin.

Table 2.--Sectors and industries, Gila Subbasin

1. Range livestock
2. Feeder livestock
3. Dairy
4. Forage, feed & food crops
5. Cotton
6. Vegetables
7. Citrus crops
8. Forestry
9. All other agriculture
10. Uranium
11. Copper
12. All other mining
13. Food & kindred products
14. Lumber & wood products
15. Furniture & fixtures
16. Paper & pulp
17. Chemicals
18. Primary metals
19. Printing & publishing
20. Fabricated metals
21. Textiles & apparel
22. Leather & leather goods
23. Stone, clay & glass
24. All other manufacturing
25. Wholesale trade
26. Service stations
27. Eating & drinking places
28. All other retail trade
29. Agricultural services
30. Lodging
31. All other services (except professional)
32. Transportation
33. Electric energy
34. All other utilities
35. Contract construction
36. Rentals & finance
37. Final payments*

---

*Final payments and final demand are comprised of the following items in all subbasins:

State & Federal government
Local government
Wages
Profits & other income
Inventory change
Depreciation allowance
Imports (exports) - other subbasins
Imports (exports) - outside Colo. River Basin

Procedures and results are oriented to four basic sets of economic activity for each subbasin:

1. Base year 1960
2. Unconstrained projections, 1980 and 2010
3. Water quantity constrained projections 1980 and 2010
4. Water quality constrained projections, 1980 and 2010

The base year 1960 is discussed concurrently with the constrained projections. This major section is followed by an analysis of projected water quantity and quality constraints.

The usual note is made that "projections" are not "forecasts" or "expectations" of events. "Projections" are based on specific assumptions as nearly as available information and judgments permit. Projections hold only to the extent that (1) the assumptions are adequate and (2) history duplicates the assumptions. For example, in the current study, the assumption of 1960 price levels and relations for 1980 and 2010 will likely not prevail as those years arrive; however, this assumption is useful for current decision making. This price assumption is also not inconsistent with Senate Document 97[1/] and the prices being used by Federal Departments in resource development evaluations.

POPULATION

In 1960, about 1,800,000 people lived in the Colorado River Basin (table 3). The population had increased to more than 2,000,000 by 1962. A large portion of the total lived in the Gila Subbasin (Phoenix-Tucson area). Only about a sixth of the total population was in the Upper Basin. The population for four of the subbasins was only slightly more than 100,000 each in 1960.

An independent consultant developed projections of 4,300,000 persons in the Colorado River Basin in 1980 and nearly 8,500,000 in 2010 (table 3). Again, the increase and large portion of the total is projected for the Gila Subbasin. These projections are "medium" of three projections made by this consultant. Low projections were 3,400,000 in 1980 and 6,200,000 in 2010. These "medium" projections were used in projections of economic activity and demand for water in the subbasin input-output analyses.

1/ Water Resources Council. Policies, Standards, and Procedures in the Formulation, Evaluation, and Review of Plans for Use and Development of Water and Related Land Resources. Senate Document 97. U.S. Govt. Print. Off. 1962. Page 12, Sec. V G-3.

Table 3.--Population, by subbasins, Colorado River Basin, 1960, 1980, 2010

Subbasin	1960	1980[1]	2010[1]
Green	102,917	100,283[2]	109,509[2]
Upper Main Stem ...	128,079	167,649[2]	202,102[2]
San Juan	107,045	155,975	226,790
Little Colorado ...	105,641	234,501	364,825
Gila	1,159,374	3,010,043	6,336,420
Lower Main Stem ...	235,546	655,568	1,218,350
Colorado River Basin	1,838,602	4,324,019	8,457,996

1/ Medium projection.
2/ Without oil shale development.

Colorado Economic Base Study

WATER SUPPLY AND USE ASSUMPTIONS

As a basic operating framework, the decision was made at the beginning of the study to conduct the analysis within the framework of the two river basin compacts and of the decision of the U.S. Supreme Court concerning allocation of water supply, recognizing that final determinations had not been made as to available long-term water supplies in the Basin and to specific meanings of the compacts and decisions. A major further associated point is that the study and analysis did not presume to allocate water supplies among subbasins, areas, states, or the Upper and Lower Basins on the basis of economic or other evaluation criteria. The water rights and allocations of the compacts and court decisions were retained to the extent they had been estimated at the time of the study. No appraisals were made of returns and benefits of water uses in alternative areas or subbasins.

Projections are based on a single water resource development situation. The agricultural projections include specific Federal projects, mostly in process of construction or authorized for construction. A major exception to this general assumption is that the Central Arizona Project (in the proposed stage at initiation of this study) is included in the projections for the Gila Subbasin. Timing of development--1980 or 2010--is based on informed judgments and available information.

The analyses do not include use of water presently exported or proposed for export out of the Colorado River Basin. Nor does the analysis include any water used or economic activity in the State of California or Mexico based on Colorado River water. Among other considerations, analysis

of these water uses and the associated economic activity would have enlarged the scope of the study substantially beyond any possibility of accomplishment within the time available.

A depletion or net disappearance concept was utilized with respect to water use and requirements. However, larger quantities of water diversions and applications are necessary in agriculture because less than 100 percent efficiencies in use are achieved. This approach means also that large quantities of water return to the channels and are re-applied (re-used) for irrigation and other purposes; this return flow and re-use, of course, are basic to water quality considerations.

LAND OWNERSHIP

About 70 percent of the land area of the Colorado River Basin is in Federal ownership (table 4). Twenty-three percent is privately owned.

The Lower Basin has a somewhat greater percentage in Federal ownership and substantially less, relatively, in private ownership than the Upper Basin. Federal ownership in all subbasins amounts to more than 60 percent of total land areas. Private ownership ranges from 31 percent in the Green and Little Colorado Subbasins to only 11 percent in the Lower Main Stem Subbasin.

Thirty percent of the Federal land in the Colorado River Basin is administered by the Forest Service and 51 percent by the Bureau of Land Management (table 4). The Forest Service lands are relatively more important in the Upper Main Stem, Little Colorado, and Gila Subbasins, while Bureau of Land Management administers relatively more Federal land in Green, San Juan, and Lower Main Stem Subbasins.

Thus, public land policy is extremely important in the Colorado River Basin. These policies affect the use and output of these large areas of land. Projected economic activity in each subbasin is highly dependent on public programs. Timber, forage and livestock production of the future, as well as other major uses of land such as recreation, hinge on these activities. Finally, a highly critical element is the fact that most of the water available in the Basin originates on public land.

RANGE FORAGE AND TIMBER USE AND DEVELOPMENT

Resource experts, primarily from the U.S. Forest Service, the U.S. Bureau of Land Management, the U.S. Bureau of Indian Affairs, and respective State agencies supplied information and judgments on prospects and potentials of range forage and timber development and use as a basis for projections. The basic premise with respect to both industries is a long-term, sustained yield concept.

Table 4.--Land ownership in the Colorado River Basin, by subbasins 1/

Subbasin	Private land	State & local govt.	Federal land: Total	Federal land: Forest Service 2/	Federal land: Bur. of Land Mgt. 2/
	- - - - - -	- - - - - -	Percent	- - - - - -	- - - - - -
Green................	31	5	64	24	69
Upper Main Stem	27	2	71	51	46
San Juan	29	4	67	23	70
Upper Basin........	29	4	67	31	63
Little Colorado......	31	6	63	59	33
Gila	22	16	62	55	34
Lower Main Stem	11	4	85	13	45
Lower Basin........	19	9	72	30	40
Total Colorado River Basin	23	7	70	30	51

1/ Year of data varied among states from 1958 to 1960. Based on "representative" counties.

2/ Portion of total federal.

U.S. Public Health Service, "Land Ownership in the Colorado River Basin." Denver, Colo., Jan. 1963. Processed. 15 pages.

Improvement in range forage output was recognized. However, the uses of large acreages of rangeland are continually changing to other primary uses such as recreation and watershed management. In balance, the range livestock industry in the Colorado River subbasins is projected to hold at about its present level through 1980, with some increase by 2010. The feeder livestock industry is projected to increase substantially in some subbasins, based on increased production and imports of feed.

The forest and lumber and wood industries show projected increases in total value output.

UNCONSTRAINED PROJECTIONS OF AGRICULTURE

Resource Base 1960

As a base level of economic activity and of relationships, six subbasin models were developed for 1960 activity. Transactions tables were prepared and direct and indirect coefficients were calculated. Projections for 1980 and 2010 used 1960 as a point of departure in terms of total gross output and relations among industries.

Cropland acreages

A large portion of land in the Colorado River Basin is used for grazing of range livestock. However, agricultural income is largely from harvested cropland, primarily irrigated.

In 1960, about 2,600,000 acres of land was irrigated in the Colorado River Basin for crop production (table 5). Acreage-wise this total was about evenly distributed between the Upper and Lower Basins. The Gila Subbasin had substantially the largest acreage of irrigated land of all subbasins and the Green Subbasin was second largest in terms of acres irrigated.

Cropping pattern

Crops in the Upper Basin are primarily forage and feed for the livestock industry (table 6). Small acreages of fruit, vegetables, and sugar beets are produced in the Upper Main Stem Subbasin.

Total crop acreages in Little Colorado Subbasin are relatively small and are mostly used for hay and grain (table 7). Both Gila and Lower Main Stem Subbasins contain large acreages of irrigated land which is used intensively (tables 8 and 9). Cotton, vegetables, and citrus are highly important in these two subbasins.

Table 5.--Irrigated cropland, by subbasins, Colorado River Basin, 1960, 1980, 2010

Subbasin	1960	1980	2010
	Acres	Acres	Acres
Green			
Total irrigated..............	654,446	701,651	729,571
Cropland irrigated...........	(415,363)	(462,568)	(490,488)
Upper Main Stem			
Total irrigated..............	518,534	567,774	655,054
Cropland harvested...........	(343,334)	--	--
San Juan			
Irrigated land...............	192,300	280,000	399,000
Total Upper Colo. Irrigated..	1,365,280	1,549,425	1,783,625
Little Colorado	23,700	32,000	33,000
Gila	1,025,000	938,000	763,000
Lower Main Stem................	224,184	287,088	332,128
Total Lower Colo. Irrigated..	1,272,884	1,257,088	1,128,128
Total Colo.River Basin Irrigated	2,638,164	2,806,513	2,911,753
Percent	100	106	110

Table 6.--Cropping pattern in Upper Colorado Subbasins, 1960

Crop	Green Subbasin	Upper Main Stem Subbasin	San Juan Subbasin
	Acres	Acres	Acres
Irrigated			
Alfalfa	117,200	115,705	51,196
Clover, etc.	99,100	88,370	12,112
Wild hay	135,700	16,352	2,412
Small grains	32,500	41,119	17,361
Other hay	7,000	7,720	3,107
Dry beans	--	9,984	929
Corn	--	30,782	5,589
Potatoes	--	1,469	923
Sugar beets	--	5,611	--
Vegetables	--	2,103	--
Fruit	--	15,098	1,496
Other	23,863	9,021	6,575
Total harvested..	415,363	343,334	101,700
Other irrigated..	239,083	175,200	90,600
Total irrigated	654,446	518,534	192,300
Dryland crops	130,000	--	106,900

Table 7.--Cropping pattern, Little Colorado Subbasin, 1960 and projected 1980 and 2010

Crop	1960	1980	2010
	- - - - - - - - - -	Acres - - - - - - - - - - -	
Alfalfa hay	10,100	15,000	14,800
Barley...............	574	1,800	1,900
Corn silage..........	0	0	0
Sorghum grain........	500	0	0
Oats.................	495	1,500	1,800
Wheat................	1,900	2,600	2,600
Corn for grain.......	13,028	17,600	15,900
Sugar beets..........		0	0
Sorghum silage.......	0		
Miscellaneous hay....	2,259	3,500	0
Alfalfa seed.........	0	0	0
Bermuda grass seed ..	0	0	0
Dry beans............	1,900		
Cotton...............	0	0	0
Cottonseed...........	-----	-----	-----
Vegetables (total)...	126	200	300
Cantaloupes & misc. melons...........	0	0	0
Lettuce..............	0	0	0
Citrus (total)	0	-----	
Grapefruit.........	0	0	0
Oranges	0	0	0
Lemons.............	0	0	0
Other citrus.......	0	0	0
All other crops......	2,000	0	0
Total harvested......	32,882	42,200	37,300

Table 8.--Cropping pattern, Gila Subbasin, 1960 and projected 1980 and 2010

Crop	1960	1980	2010
	Acres		
Alfalfa hay.........	165,880	157,000	136,000
Barley	161,619	136,000	77,000
Corn silage	5,900	17,000	14,000
Sorghum grain.......	93,458	95,000	60,000 1/
Oats................	3,000	3,000	3,000
Wheat...............	17,999	18,000	12,000
Corn for grain......	19,750	0	0
Sugar beets.........	0	0	0
Sorghum silage......	31,242	0	0
Miscellaneous hay...	4,500	4,000	3,500
Alfalfa seed........	8,100	0	0
Bermuda grass seed..	557	300	300
Dry beans...........	0	0	0
Cotton..............	391,000	390,000	374,000
Cottonseed..........	-------	-------	-------
Vegetables (total)..	68,000	60,000	50,000
Cantaloupes & misc. melons..........	(2,650)	(2,400)	(1,950)
Lettuce...........	(45,600)	(42,000)	(34,200)
Citrus (total)......	16,692	18,000	20,000
Grapefruit........	(4,545)	(5,000)	(6,000)
Oranges	(10,637)	(10,000)	(12,000)
Lemons	(1,510)	(3,000)	(4,000)
Other citrus	0		
All other crops	37,303	47,000	11,200
Total harvested.....	1,025,000	938,000	763,000

1/ Silage crops.

Table 9.--Cropping pattern, Lower Main Stem Subbasin, 1960 and projected 1980 and 2010

Crop	1960	1980	2010
	Acres		
Alfalfa hay	68,572	79,451	78,733
Barley	20,252	20,679	23,082
Corn silage.........	1,586	9,168	6,944 1/
Sorghum grain	15,890	21,502	20,125
Oats	3,283	1,515	1,171
Wheat	10,085	8,864	8,510
Corn for grain	1,501	0	0
Sugar beets	0	1,550	1,650
Sorghum silage......	3,071	0	0
Miscellaneous hay....	7,863	6,740	7,358
Alfalfa seed........	10,262	3,590	3,650
Bermuda grass seed ..	10,843	850	994
Dry beans	0	0	0
Cotton	34,665	41,680	45,969
Cottonseed..........	------	------	------
Vegetables (total)...	42,502	65,559	84,651
Cantaloupes & misc. melons..........	(15,485)	(26,730)	(32,476)
Lettuce	(20,555)	(24,943)	(31,842)
Citrus (total).......	14,914	24,082	36,303
Grapefruit.........	(2,075)	(2,614)	(6,217)
Oranges...........	(6,609)	(13,064)	(16,418)
Lemons............	(5,790)	(8,404)	(13,668)
Other.............	(440)		
All other crops......	0	3,325	4,238
Total harvested	245,289	287,555	356,228

1/ Silage crops.

Total gross output--quantities and values

Aggregate quantities of crop and livestock production, 1960 and projections, were estimated for each subbasin (tables 10 and 11). These estimates show absolute and relative changes in production. They are useful also for considerations of projected demands for agricultural goods and services within a national framework.

The value of crop production is indicated by total gross output magnitudes per acre of irrigated cropland (table 12). These values are about $115-$120 per acre in the Upper Colorado Subbasins. Similar values amount to about $400 per acre in Gila and Lower Main Stem Stubbasins.

Table 12.--Total gross output per acre of irrigated cropland, agricultural sectors, by subbasins, 1960, 1980 and 2010

Subbasin	1960	Unconstrained 1980	Unconstrained 2010
	Dollars	Dollars	Dollars
Green	118	125	130
Upper Main Stem	123	140	184
San Juan	113	100	108
Little Colorado 1/	532	551	654
Gila	382	658	1,101
Lower Main Stem	412	659	880

1/ High averages reflect the relatively great importance of range livestock in total gross output for the subbasin.

Total gross output for all economic activity was about $1 1/4 billion in each of the Upper Colorado Subbasins, $3/4 billion for Little Colorado Subbasin, $2 1/2 billion in Lower Main Stem and $9 1/2 billion in Gila Subbasin (table 13). Total gross output for the Colorado River Basin in 1960 was estimated at about $16,379 million (table 13). Total gross output for all processing sectors was a little more than $7 billion in 1960.

Agricultural sectors constitute a relatively small portion of total economic activity (table 14). In 1960, total gross output of all agricultural sectors in the six subbasins was about $618,000,000 of which nearly two-thirds was produced in Gila Subbasin. Agricultural output in the basin amounted to less than 10 percent of output in the processing sectors and about 4 percent of all economic activity.

Agricultural sectors in combination with two closely related sectors--food and kindred products and agricultural services--resulted in total agricultural activity of more than $918 million in 1960, or about 13 percent of output of the processing sectors (table 14). About two-thirds of

Table 10.--Production of crops and livestock and livestock products, Lower Colorado Basin by Subbasins, 1960 and "unconstrained" projections 1980 and 2010

Item	Unit	1960			
		Lower Main Stem	Gila	Little Colorado	Total
Alfalfa hay........	Tons	262,580	677,713	25,200	965,493
Barley	Thou.bu.	1,219	10,170	12	11,401
Corn for grain.....	Thou.bu.	47	635	23	705
Grain sorghums.....	Cwt.	432,000	2,691,600	5,500	3,129,100
Oats...............	Thou.bu.	53	41	7	101
Wheat..............	" "	300	594	26	920
Corn silage........	Tons	21,937	81,000	0	102,937
Sorghum silage.....	Tons	49,136	499,872	0	549,008
Misc. hays.........	Tons	14,053	8,700	2,327	25,080
Alfalfa seed.......	Cwt.	20,627	11,145	0	31,772
Bermuda grass seed.	Cwt.	58,252	2,991	0	61,243
Dry beans..........	Cwt.	0	0	2,139	2,139
Cotton.............	Bales	77,846	768,826	0	846,672
Cottonseed.........	Tons	31,110	318,357	0	349,467
Vegetables (total).		------	-------	-----	-------
Broccoli.........	Cwt.	36,014	72,028	0	108,042
Cabbage..........	Cwt.	40,000	136,325	0	176,325
Cantaloupes & misc. melons.........	Cwt.	1,644,860	338,000	0	1,982,860
Carrots..........	Cwt.	108,800	273,000	0	381,800
Lettuce..........	Cwt.	3,220,025	8,008,000	0	11,228,025
Celery...........	Cwt.	0	140,000	0	140,000
Onions	Cwt.	146,330	400,000	0	546,330
Potatoes.........	Tons	30,720	97,368	0	128,088
Watermelons	Tons	10,880	24,343	0	35,223
Citrus (total)		------	------	-----	------
Grapefruit.......	Thou.Pkd.boxes	805	2,258	0	3,063
Oranges..........	" " "	199	1,058	0	1,257
Lemons...........	" " "	847	248	0	1,095
Other citrus.....	" " "	68	0	0	68
Livestock & livestock products					
Whole milk produced	Cwt.	309,381	4,436,961	48,780	4,795,122
Dairy cull cows...	Cwt.liveweight	16,033	206,053	3,928	226,014
Calves from dairy herds	" "	1,200	19,467	320	20,987
Feeder & stockers...	" "	269,739	1,291,186	264,520	1,825,445
Slaughter cattle..	" "	824,779	3,871,111	24,178	4,720,068
Sheep & lambs,goats	" "	45,338	48,951	147,086	241,375
Wool and mohair..	Lbs.	842,658	916,216	2,113,071	3,871,945
Hogs...............	Cwt.	11,194	0	1,125	12,319
Poultry & poultry prod.					
Eggs	Thou.doz.	1,023	14,566	269	15,858
Broiler and other	Thou.lbs.	213	6,444	183	6,840
Turkeys	Thou.lbs.	7,090	1,888	0	8,978

Table 10.--(continued)

Item	Unit	1980 Lower Main Stem	Gila	Little Colorado	Total
Alfalfa hay.........	Tons	515,061	1,116,270	60,000	1,691,331
Barley.............	Thou.bu.	1,308	14,337	113	15,758
Corn silage.........	Tons	200,253	346,800	0	547,053
Sorghum-grain equiv.	Cwt.	1,270,768	4,731,000	0	6,001,768
Oats...............	Thou.bu.	65	141	38	244
Wheat..............	" "	428	894	94	1,416
Corn for grain	" "	0	0	651	651
Sugar beets	Tons	18,648	0	0	18,648
Misc. hay..........	Tons	8,316	10,000	7,000	25,316
Alfalfa seed........	Cwt.	7,156	0	0	7,156
Bermuda grass seed..	Cwt.	7,097	927	0	8,024
Cotton	Bales	138,208	1,193,400	0	1,331,608
Cottonseed..........	Tons	55,283	477,360	0	532,643
Vegetables (total)..		------	-------	-----	-------
Broccoli..........	Cwt.	37,624	57,400	0	95,024
Cabbage	Cwt.	129,167	186,900	0	316,067
Cantaloupes & misc. melons..........	Cwt.	6,208,332	599,440	0	6,767,772
Carrots...........	Cwt.	763,251	427,680	0	1,190,931
Lettuce...........	Cwt.	6,351,891	13,902,000	0	20,253,891
Celery	Cwt.	0	0	0	0
Onions	Cwt.	443,137	658,080	0	1,101,217
Potatoes..........	Tons	72,991	170,820	0	243,811
Watermelons.......	Tons	17,680	42,495	0	60,175
Citrus (total)		------	------	----	------
Grapefruit........	Thou.Pkd.Boxes	1,194	3,820	0	5,014
Oranges	" " "	4,024	3,040	0	7,064
Lemons	" " "	3,113	756	0	3,869
Livestock & livestock products					
Whole milk produced	Cwt.	855,000	11,713,577	91,170	12,659,747
Dairy cull cows...	Cwt.liveweight	42,750	543,980	7,294	594,024
Calves from dairy herds	" "	2,565	51,393	590	54,548
Feeders & stockers..	Cwt.liveweight	261,640	1,743,101	348,900	2,353,641
Slaughter cattle..	" "	1,440,000	5,109,866	34,720	6,584,586
Sheep, lambs, goats	" "	57,168	66,084	194,000	317,252
Wool and mohair...	Lbs.	844,736	1,236,892	2,787,140	4,868,768
Hogs	Cwt.	16,119	0	1,538	17,657
Poultry & poultry products					
Eggs..............	Thou.doz.	1,473	34,521	367	36,361
Broiler and other.	Thou. lbs.	306	15,272	250	15,828
Turkeys	Thou. lbs.	10,209	4,474	0	14,683

Table 10.--(continued)

Item	Unit	2010 Lower Main Stem	Gila	Little Colroado	Total
Alfalfa hay	Tons	601,321	1,400,800	88,800	2,090,921
Barley...............	Thou.bu.	1,818	11,004	20	12,842
Silage crops.........	Tons	226,374	456,400	0	682,774
Sorghum grain	Cwt.	1,462,343	4,068,000	0	5,530,343
Oats.................	Thou.bu.	73	165	67	305
Wheat	Thou.bu.	416	803	141	1,360
Corn for grain	Thou.bu.	0	0	954	954
Misc. hay	Tons	18,395	14,000	0	32,395
Sugar beets	Tons	22,687	0	0	22,687
Alfalfa seed	Cwt.	14,121	0	0	14,121
Bermuda grass seed ..	Cwt.	4,278	1,290	0	5,568
Cotton	Bales	187,441	1,436,160	0	1,623,601
Cottonseed	Ton	74,976	574,464	0	649,440
Vegetables (total)		------	-------	----	-------
Broccoli	Cwt.	257,463	48,740	0	306,203
Cabbage	Cwt.	477,171	185,160	0	662,331
Cantaloupes & misc. melons...........	Cwt.	9,460,259	554,240	0	10,014,499
Carrots............	Cwt.	1,171,414	423,720	0	1,595,134
Lettuce............	Cwt.	10,777,716	13,356,000	0	24,133,716
Celery	Cwt.	0	0	0	0
Onions	Cwt.	489,280	650,880	0	1,140,160
Potatoes	Tons	230,600	198,860	0	429,460
Watermelons........	Tons	27,804	122,000	0	149,804
Citrus...............					
Grapefruit	Thou.boxes	3,357	6,206	0	9,563
Oranges	" "	6,246	4,962	0	11,208
Lemons	" "	6,004	1,365	0	7,369
Livestock & livestock	products				
Whole milk produced	Cwt.	1,350,900	24,715,647	148,516	26,215,063
Dairy cull cows....	Cwt.livewt.	67,545	1,147,797	11,882	1,227,224
Calves from dairy herd	" "	4,053	108,439	961	113,453
Feeders & stockers...	" "	273,937	2,281,719	392,861	2,948,517
Slaughter cattle...	" "	1,950,000	6,724,444	42,289	8,716,733
Sheep, lambs & goats	" "	59,855	86,504	218,400	364,759
Wool and mohair....	Lbs.	884,439	1,619,092	3,138,320	5,641,851
Hogs	Cwt.	25,629	0	1,846	27,475
Poultry & poultry products					
Eggs	Thou.doz.	2,342	43,013	440	45,795
Broilers and other.	Thou.lbs.	487	19,029	300	19,816
Turkeys	Thou.lbs.	16,232	5,575	0	21,807

Table 11.--Production of crops and livestock and livestock products, Upper Colorado Basin by subbasins, 1960 and "unconstrained" projections 1980 and 2010

Item	Unit	1960 Green Subbasin	1960 Upper Main Stem Subbasin	1960 San Juan Subbasin	1960 Total Basin
Corn for grain......	Bu.	70,143	1,263,722	170,576	1,504,441
Corn for silage.....	Tons	62,000	157,045	28,876	247,921
Sorghums for grain..	Cwt.	0	26,475	0	26,475
Barley.............	Bu.	1,212,136	858,250	423,484	2,493,870
Oats...............	Bu.	586,038	796,893	250,723	1,633,654
Rye................	Bu.	6,879	7,256	6,311	20,446
Alfalfa & alfalfa mix.	Tons	276,407	291,226	133,780	701,413
Other hay..........	Tons	285,750	168,558	29,239	483,547
Wheat..............	Bu.	1,436,300	762,950	831,490	3,030,740
Sugar beets........	Tons	9,500	120,726	0	130,226
Dry beans..........	Cwt.	0	287,714	185,127	472,841
Potatoes...........	Cwt.	31,054	287,766	183,516	502,336
Apples	Bu.	0	1,315,833	197,479	1,513,312
Peaches............	Bu.	0	777,971	44,025	821,996
Pears..............	Bu.	0	44,058	5,036	49,094
Cherries, sour......	Tons	0	903	0	903
Cherries, sweet	Tons	0	179	0	179
Onions	Cwt.	0	304,889	0	304,889
Lettuce............	Cwt.	0	47,308	0	47,308
Tomatoes	Cwt.	0	14,167	0	14,167
Milk, whole	Cwt.	1,322,718	442,447	314,964	2,080,129
Cream	Lbs.B.F.	392,503	888,502	252,803	1,533,080
Eggs	Doz.	898,700	1,475,700	794,000	3,168,400
Chickens...........	Lbs.	229,709	191,300	154,000	575,009
Turkeys	Lbs.	113,995	501,900	150,000	765,895
Cattle & calves.....	Cwt.livewt.	1,094,586	1,014,794	406,911	2,516,291
Sheep & lambs & goats	" "	544,686	329,181	181,376	1,055,243
Hogs & pigs........	" "	36,278	83,000	17,580	136,858
Wool & mohair	Lbs.	8,302,764	3,852,918	2,500,000	14,655,682

Table 11.--(continued)

Item	Unit	1980 Green Subbasin	1980 Upper Main Stem Subbasin	1980 San Juan Subbasin	1980 Total Basin
		1,000			
Corn for grain	Bu.	71	2,047	432	2,550
Corn for silage	Tons	70	254	85	409
Sorghums for grain	Cwt.	0	159	0	159
Barley	Bu.	1,343	941	1,321	3,605
Oats	Bu.	645	679	471	1,795
Rye	Bu.	0	0	0	0
Alfalfa & alfalfa mix..	Tons	343	396	209	948
Other hay	Tons	295	263	38	596
Wheat	Bu.	1,522	754	906	3,182
Sugar beets	Tons	17	164	0	181
Dry beans	Cwt.	0	362	273	635
Potatoes	Cwt.	25	269	328	622
Apples	Bu.	0	1,988	258	2,246
Peaches	Bu.	0	1,183	55	1,238
Pears	Bu.	0	67	0	67
Cherries, sour	Tons	0	2	0	2
Cherries, sweet	Tons	0	0	0	0
Onions	Cwt.	0	430	0	430
Lettuce	Cwt.	0	66	0	66
Tomatoes	Cwt.	0	20	0	20
Milk, whole	Cwt.	1,622	453	775	2,850
Cream	Lbs.B.F.	0	0	0	0
Eggs	Doz.	1,461	1,045	1,059	3,565
Chickens	Lbs.	242	130	192	564
Turkeys	Lbs.	190	342	180	712
Cattle & calves	Cwt.livewt	1,245	1,918	495	3,658
Sheep, lambs & goats...	" "	709	247	202	1,158
Hogs & pigs	" "	41	67	23	131
Wool & mohair..........	Lbs.	10,588	2,889	3,087	16,564

Table 11.--(continued)

Item	Unit	2010 Green Subbasin	2010 Upper Main Stem Subbasin	2010 San Juan Subbasin	2010 Total Basin
		- - - - - - - 1,000	- - - - - - - - -		
Corn for grain.........	Bu.	75	4,012	575	4,662
Corn for silage........	Tons	80	498	168	746
Sorghums for grain.....	Cwt.	0	485	0	485
Barley.................	Bu.	1,500	1,203	3,844	6,547
Oats...................	Bu.	742	684	1,083	2,509
Rye....................	Bu.	0	0	0	0
Alfalfa & alfalfa mix.	Tons	375	618	521	1,514
Other hay..............	Tons	324	444	57	825
Wheat..................	Bu.	1,750	802	1,139	3,691
Sugar beets............	Tons	25	233	0	258
Dry beans..............	Cwt.	0	404	269	673
Potatoes...............	Cwt.	20	195	599	814
Apples.................	Bu.	0	3,294	377	3,671
Peaches................	Bu.	0	1,951	84	2,035
Pears..................	Bu.	0	110	0	110
Cherries, sour.........	Tons	0	3	0	3
Cherries, sweet........	Tons	0	0	0	0
Onions.................	Cwt.	0	666	0	666
Lettuce................	Cwt.	0	103	0	103
Tomatoes...............	Cwt.	0	31	0	31
Milk, whole............	Cwt.	1,666	580	1,905	4,151
Cream..................	Lbs.B.F.	0	0	0	0
Eggs...................	Doz.	1,500	370	2,131	4,001
Chickens...............	Lbs.	271	52	301	624
Turkeys................	Lbs.	200	144	286	630
Cattle & Calves........	Cwt.livewt.	1,325	3,165	753	5,243
Sheep & lambs & goats..	" "	784	180	297	1,261
Hogs & pigs............	" "	43	42	39	124
Wool & mohair..........	Lbs.	12,735	2,109	4,537	19,381

Table 13.--Total gross output (processing sectors) by subbasins, Colorado River Basin, 1960, and unconstrained 1980 and 2010

Subbasin	1960 1/	1980	2010
	- - - - - - - 000 dollars - - - - -		
Green	508,213 (1,127,610)	711,968	1,170,784
Upper Main Stem	540,386 (1,295,320)	862,010	1,553,458
San Juan	570,605 (1,289,488)	793,754	1,561,175
Little Colorado	376,263 (771,061)	902,535	2,056,112
Gila	4,107,940 (9,477,564)	13,425,325	32,749,158
Lower Main Stem	1,075,574 (2,418,022)	3,865,187	9,529,416
Totals	7,178,981	20,560,779	48,620,103
	- - - - - - - - Percent - - - - - - -		
Green	100	140	230
Upper Main Stem	100	160	287
San Juan	100	139	274
Little Colorado	100	240	546
Gila	100	327	797
Lower Main Stem	100	359	886

1/ Figures in parentheses include final payment.

Table 14.--Total gross output, agricultural and related sectors, by subbasins, 1960 and unconstrained 1980 and 2010

Subbasin	1960	1980	2010
	- - - - - (000) - - - - -		
	Agricultural Sectors		
Green	49,000	57,822	64,041
Upper Main Stem......	51,007	79,496	120,432
San Juan.............	21,817	27,961	43,312
Little Colorado......	12,610	17,641	21,580
Gila.................	391,078	617,649	840,071
Lower Main Stem......	92,368	194,659	300,026
Totals...........	617,880	995,228	1,389,462
	Food & Kindred Products		
Green................	8,253	10,557	13,348
Upper Main Stem......	19,143	34,794	50,110
San Juan.............	8,067	15,271	27,019
Little Colorado......	1,185	2,454	4,352
Gila.................	190,301	546,863	849,431
Lower Main Stem......	15,889	54,074	112,142
Totals...........	242,838	664,013	1,056,402
	Agricultural Services		
Green 1/.............	0	0	0
Upper Main Stem......	4,754	6,829	10,816
San Juan	737	919	1,608
Little Colorado 1/...	0	0	0
Gila	31,982	45,893	57,197
Lower Main Stem	19,961	57,898	102,222
Totals...........	57,434	111,539	171,843

1/ No agricultural services sectors defined in these two subbasins.

output value for these three groups of agricultural sectors was produced in the Gila Subbasin.

Estimated value of forestry output ($14,486,000) and lumber and wood products output ($77,467,000) totaled $91,953,000 in 1960 (table 15).

Range livestock sales predominated among agricultural sectors in 1960 in Green, Upper Main Stem, San Juan, and Little Colorado Subbasins (table 16). Cotton in the Gila Subbasin exceeded by far any other agricultural sector in 1960 in total gross output. Feeder livestock in Gila Subbasin and vegetables and melons in the Gila and Lower Main Stem Subbasins ranked next in importance as measured by TGO.

Direct and indirect coefficients

The magnitude of combined direct and indirect coefficients is shown for illustrative purposes for the Lower Main Stem in 1960 and 1980 (table 17). These coefficients show the interacting effects through the economy of $1.00 of increased sales by the respective sector.

It will be noted that vegetable and citrus sectors rank very high (greater than 2.0) in the Lower Main Stem Subbasin (table 17). Dairy products and feeder livestock have relatively high coefficients also. Transportation, for example, shows a coefficient of only 1.2.

These coefficients were computed for all subbasins, 1960 and all projected years and situations.

Projected 1980 and 2010

Projections in this study were made in three major stages: (1) unconstrained, (2) water quantity constrained, and (3) water quality constrained. While the projections discussed in this section are referenced as "unconstrained," as noted earlier, from a practical standpoint it was desirable to include water availability and development restrictions in making agricultural projections.

New agricultural development in the Colorado River Basin will be based almost entirely on irrigation. Thus, it is not especially useful in terms of a single projection to disregard water supply constraints. Further, this new development will likely be primarily under the Federal reclamation program. The "unconstrained" projections of agricultural sectors were coordinated to the extent feasible with prospective Federal development of water supply for the target years 1980 and 2010.

Demand for goods and services

For several years, U.S. Economic Research Service has been involved in projections of national demand for agricultural goods and services. In recent years, under the program of the U.S. Water Resources Council,

Table 15.--Total gross output, forestry and lumber and wood products, by subbasins, 1960 and unconstrained 1980 and 2010

Subbasin	1960	1980	2010
	- - - - - -	(000)	- - - - - - - - -
		Forestry	
Green	939	2,022	2,923
Upper Main Stem	1,952	3,658	8,011
San Juan	1,955	2,697	2,971
Little Colorado	4,499	6,078	6,456
Gila	1,645	2,100	2,139
Lower Main Stem	3,496	3,979	4,534
Totals	14,486	20,534	27,034
		Lumber & Wood Products	
Green	2,380	5,133	5,278
Upper Main Stem	5,033	6.229	10,805
San Juan	5,284	6,416	6,679
Little Colorado	22,145	31,120	33,944
Gila	28,428	6,707	131,354
Lower Main Stem	14,197	16,999	19,791
Totals	77,467	72,604	207,851

Table 16.--Total gross output by agricultural sectors and subbasins, 1960 unconstrained 1980 and 2010, and quality constrained 1980 and 2010

Sectors	Unconstrained 1960	Unconstrained 1980	Unconstrained 2010	Quality constrained 1/ 1980	Quality constrained 1/ 2010
	- - - - - - - 000 dollars - - - - - - -				
			Green Subbasin		
1. Agriculture.........	49,000	57,822	64,041	No change	No change
2. Forestry............	939	2,022	2,923		
6. Food & Kindred......	8,253	10,557	13,348		
7. Lumber & Wood.......	2,380	5,133	5,278		
			Upper Main Stem		
1. Range Livestock.....	28,284	30,083	44,377		
2. Feeder Livestock....	4,010	26,882	45,141		
3. Dairy...............	3,155	2,577	3,324		
4. Food & Field Crops..	5,793	6,884	8,061		
5. Truck Crops.........	862	1,210	1,879		
6. Fruit...............	6,243	9,451	15,653		
8. Other Agriculture...	2,660	2,409	1,997		
Totals	51,007	79,496	120,432	No change	No change
7. Forestry............	1,952	3,658	8,011		
14. Food & Kindred......	19,143	34,794	50,110		
15. Lumber & Wood.......	5,033	6,229	10,805		
24. Agr. Services	4,754	6,829	10,816		
			San Juan Subbasin		
1. Range Livestock	15,142	17,866	26,341		
2. Dairy	1,676	3,710	8,913		
3. Field Crops.........	3,515	4,477	5,022		
4. Fruit...............	641	812	1,200		
6. Other Agriculture...	843	1,096	1,836		
Totals	21,817	27,961	43,312	No change	No change
5. Forestry	1,955	2,697	2,971		
11. Food & Kindred	8,067	15,271	27,019		
12. Lumber & Wood	5,284	6,416	6,679		
20. Agr. Services	737	919	1,608		
			Little Colorado Subbasin		
1. Range Livestock	10,241	13,513	15,215		
2. Feeder Livestock ...	550	790	962		
3. Dairy...............	336	638	1,093		
4. Forage, Feed & Food	1,216	2,329	3,825		
6. Other Agriculture ..	267	371	485		
Totals	12,610	17,641	21,580	No change	No change
5. Forestry	4,499	6,078	6,456		
11. Food & Kindred	1,185	2,454	4,352		
12. Lumber & Wood	22,145	31,120	33,944		

1/ "No change" applies to all sectors in subbasin.

Table 16.--(continued)

Sectors	Unconstrained 1960	Unconstrained 1980	Unconstrained 2010	Quality constrained 1980	Quality constrained 2010
	000 dollars				
	Gila Subbasin				
1. Range Livestock....	33,652	45,596	59,700	45,592	59,666
2. Feeder Livestock...	87,069	115,599	151,299	115,589	151,255
3. Dairy.............	27,371	72,399	152,796	72,392	152,658
4. Forage, Feed & Food	37,209	57,544	59,941	57,433	59,896
5. Cotton............	141,244	214,861	258,568	214,799	258,462
6. Vegetables........	48,388	78,050	96,678	78,028	96,636
7. Citrus............	6,788	11,286	18,686	11,280	18,671
9. Other Agriculture..	9,357	22,214	42,403	22,211	42,385
Totals	390,078	617,649	840,071	617,324	839,629
8. Forestry..........	1,645	2,100	2,139	2,100	2,139
13. Food & Kindred.....	190,301	546,863	849,431	546,816	849,232
29. Agr. Services......	31,982	45,893	57,197	45,871	57,169
14. Lumber & Wood......	28,428	67,407	131,354	67,406	131,353
	Lower Main Stem				
1. Range Livestock....	8,069	8,026	8,301	8,026	8,300
2. Feeder Livestock...	18,574	32,609	43,091	32,609	43,897
3. Dairy.............	1,965	4,435	6,277	4,434	6,273
4. Forage, Feed & Food	11,324	20,653	25,444	20,469	24,352
5. Cotton............	13,943	24,553	33,896	24,530	33,761
6. Vegetables & Melons	28,563	73,267	130,285	73,053	128,666
7. Citrus............	3,370	21,633	37,645	21,610	37,473
8. Forestry..........	3,496	3,979	4,534	3,979	4,533
9. All Other Agr.	6,560	9,483	14,277	9,471	14,204
Totals	95,864	198,638	304,560	198,181	301,459
13. Lumber & Wood......	14,197	16,999	19,791	16,999	19,789
12. Food & Kindred.....	15,889	54,074	112,142	54,071	112,130
23. Ag Services........	19,961	57,898	102,222	57,766	101,209

Table 17.--Direct and indirect coefficients, agricultural and forestry sectors with comparisons, Lower Main Stem Sub-basin 1960, and 1980 projected

Sector	1960	1980
1. Range livestock	1.307723	1.342272
2. Feeder livestock.......	1.669837	1.580248
3. Dairy.................	1.746370	1.797240
4. Forage, feed & food crops................	1.227003	1.292462
5. Cotton	1.316815	1.355623
6. Vegetable and melon products.............	2.032013	2.070400
7. Citrus crops...........	2.074217	2.149414
8. Forestry...............	1.191575	1.138232
9. All other agriculture..	1.352613	1.385621
23. Agric. services........	1.570822	1.587642
13. Lumber & wood products 1/	1.870118	1.577392
29. Contract construction 1/	1.737509	1.793949
21. Eating & drinking 1/...	1.633983	1.656037
10. Uranium 1/.............	1.559151	1.653748
12. Food & kindred prod.1/	1.544590	1.522744
24. Lodging 2/.............	1.234207	1.245156
22. All other retail 2/....	1.309154	1.320327
19. Wholesale trade 2/.....	1.311460	1.344120
26. Transportation 2/......	1.200331	1.216300

1/ Highest ranking among nonagricultural sectors.
2/ Other nonagricultural sectors with largest TGO's.

national demand has been allocated to Water Resource Regions, including the Upper Colorado Region and the Lower Colorado Region. These national projections and regional allocations were highly preliminary when projections were made for this input-output study. However, they were utilized and served as useful guides, especially in estimating directions of change in crop and livestock production where adjustments will be feasible.

Preliminary national and regional projections of demand for goods and services are shown in the Green River Subbasin report.1/ For purposes of this study, regional allocations were distributed among subbasins. Updated regional allocations of national demand to Upper and Lower Colorado Water Resource Regions are now available for reference purposes.2/

Population projections shown in an earlier section were utilized especially in estimating values and relationships for nonagricultural sectors. The Food Processing and Agricultural Services sectors are important to the agricultural projections.

New land and water development

During the next 50 years, irrigation water developments in the Colorado River Basin, based on supplies of water originating in the Basin will be used both to supplement presently short supplies and to develop new land for irrigation. Both major uses have been recognized and incorporated into projections of crop yields and total production.

Details of new project and water development and use for irrigation are presented in the individual subbasins reports. In most instances, these reports show for 1980 and 2010 the acreages to receive supplemental water and water for new land. In this section, only a summary of new land and total irrigated acreages is shown.

The projections for this study show that total irrigated acreages in the Colorado River Basin will increase from 2,638,164 acres in 1960 to 2,911,753 acres in 2010 (table 5). Of this increase of 273,589 acres, 168,349 acres would be developed by 1980 and the remainder of 105,240 acres during the 1980-2010 period (table 18).

1/ Clyde E. Stewart and Lynn W. Wilkes. An Interindustry Analysis with Emphasis on Water Used by Agriculture and Forestry, Green River Subbasin, Colorado River Basin. Economic Research Service, U.S. Dept. of Agriculture. Logan, Utah. December 1965.

2/ U.S. Dept. of Agriculture. Preliminary Projections of Economic Activity in the Agricultural, Forestry and Related Economic Sectors of the United States and Its Water Resource Regions, 1980, 2000, and 2020. Wash. D.C. August 1967. Processed.

Table 18.--Projected increases in irrigated cropland, by subbasins, 1960-80, 1980-2010, and 1960-2010

Subbasin	1960-80	1980-2010	1960-2010
	- - - - - - - - -	Acres	- - - - - - - - -
Green	47,205	27,920	75,125
Upper Main Stem	49,240	87,280	136,520
San Juan	87,700	119,000	206,700
Upper Basin	184,145	234,200	418,345
Little Colorado	8,300	1,000	9,300
Gila	-87,000	-175,000	-262,000
Lower Main Stem	62,904	45,040	107,944
Lower Basin	-15,796	-128,960	-144,756
Total Colo. River Basin	168,349	105,240	273,589

The net increase in acreage will be in the Upper Colorado Region where 418,345 acres of newly irrigated land is projected (table 18). The projections show a net decrease of 144,756 acres of irrigated crop land in the Lower Basin, because of a substantial decrease projected for the Gila Subbasin. Even with the Central Arizona Project, increased nonagricultural economic and population growth and declining groundwater tables and increased costs are projected to result in a net decrease of 262,000 acres of irrigated land in the Gila Subbasin during the next 50 years.

Technology

Substantial improvements in technology were considered in projections of agricultural output. Increased inputs, e.g., commercial fertilizer, improved varieties, and improved irrigation efficiencies are the more important changes in technology that are recognized.

Individual crop yields are shown in the subbasin reports. However, an indication of the magnitude of projected changes is reflected in the total gross outputs. Since prices are held constant, the changes in output values are quantity based.

The projected growth rates by 2010 range from 131 percent of 1960 in the Green Subbasin to 325 percent of 1960 in Lower Main Stem (table 19). It is apparent that these increases are largely reflections of changes in crop yields. Cropping pattern changes--to be reviewed

Table 19.--Projected growth of total agricultural sectors, by subbasins, Colorado River Basin, 1960, 1980, 2010

Subbasin	Unconstrained			Water quality constrained	
	1960	1980	2010	1980	2010
	- - - - -Percent - - - -			- - - - Percent - - - -	
Green	100	118	131	No change	No change
Upper Main Stem ..	100	156	236	"	"
San Juan	100	128	198	"	"
Little Colorado ..	100	140	171	"	"
Gila	100	158	215	158 1/	215 1/
Lower Main Stem ..	100	211	325	210	321

1/ Decrease less than 1 percent.

later in this report--had some influence on output. Larger acreages of irrigated land were important also, but the 2010 acreage projection is only 111 percent of 1960 for the total basin.

A more direct indication of the effects of changes in yield and cropping pattern can be found in total gross output per acre of irrigated land, recognizing that livestock and range production are included in these values (table 12). Gila output per acre increased nearly 300 percent from 1960 to 2010, while Lower Main Stem more than doubled during the same period.

Output value per acre irrigated is not maintained between 1960 and 2010. A large acreage of new irrigation is projected during the period. Possibly a slow rate of development and use of some lower quality land will result in less value output per unit of land.

The Upper Colorado subbasins showed modest increases in value of output per acre. Crops in these subbasins are largely low valued forage and grain.

Cropping pattern

The forage and grain oriented cropping patterns in the Upper Colorado subbasins are projected to remain nearly the same as in 1960. Total acreage of dry cropland will probably decrease in all subbasins because of irrigation.

Large relative and absolute changes are projected to occur in acreages of cotton, melons, lettuce, and citrus in Gila and Lower Main Stem. Marked absolute increases are projected for cotton, vegetables, and citrus in the Lower Main Stem. However, absolute

acreages of these crops are projected to decline in the Gila Subbasin because of fewer total irrigated acres projected for this subbasin.

Projected final demand

The use of input-output analysis for projections purposes involved three major steps: (1) projections of each entry in the final demand sectors of the input-output table, (2) projections of direct coefficients, and (3) a new transactions table based on projected changes in final demand and coefficients.

The heavy water and land resource orientation of agriculture led to a modified procedure for the agricultural sectors. The basic change was projection first of total gross output for each sector instead of final demand.

Total gross output was estimated on the basis of projected irrigated acreages, crop yields, input, cropping patterns, imports and exports of feed, e.g., and projected range capacity. These projected total gross outputs in combination with projected direct coefficients permitted construction of projected transaction tables including final demand sectors.

Projected total gross outputs

Total outputs of all processing sectors were projected to increase during the 50-year period from 230 percent in Green Subbasin to 800 and 900 percent for Gila and Lower Main Stem, respectively (table 13). The projected increase in these sectors was about 675 percent for the total Colorado River Basin.

Total gross output for agricultural sectors was projected to more than double from 1960 to 2010 for the total basin. Major increases (absolute and relative) are projected for Gila and Lower Main Stem, so that by 2010, these two subbasins would account for more than 80 percent of the output of agriculture in the basin compared with 78 percent in 1960.

Output in food and kindred products is projected to increase more than 400 percent by 2010 (table 14). Lumber and wood products would increase nearly three times in the same period (table 15).

Important agricultural sector increases in total gross output projected, 1960 to 2010, include feeder livestock (UMS, Gila, LMS), dairy (Gila), cotton, vegetables and melons, and citrus (Gila, LMS) (table 16). The major increase in food and kindred products would be in Gila Subbasin.

Projected direct coefficients

Traditionally, the use of input-output models for projections purposes has been characterized by constant direct coefficients. Most small area studies have also utilized national or regional coefficients.

These two assumptions have been subject to marked criticisms and have generally brought disfavor to the input-output technique for projections purposes.

In the current study, neither of the above "objectionable" assumptions was applied. Separate, independent, and original transactions tables and direct coefficients were developed for each subbasin. They were based on economic conditions and relations in the subbasins. National coefficients were not utilized.

Secondly, 1960 coefficients were not utilized in 1980 and 2010 unless trend analyses, projections or relevant economic and physical variables, and informed judgments led to this conclusion. The intent and effort clearly was to project "new" direct coefficients for 1980 and 2010.

A basic element in adjustments from 1960 coefficients to 1980 and 2010 coefficients was a "best group of firms" approach which assumes that the average technology in 1980 would equal the performance of this best 1960 group.

Using this "best firms" and other factors, an initial set of projected direct coefficients was estimated for each subbasin. The need for some adjustments in this set of coefficients was apparent. In some instances, zero magnitudes in 1960 were adjusted upward on a judgment basis. Resource limitations, especially range forage, led to downward adjustments over preliminary projections. Substantial increases were made in some instances for the use of chemicals.

As noted earlier, final demands for agricultural sectors were then estimated on the basis of projected total gross outputs and projected direct coefficients. The final major step at this stage was calculation of the combined direct and indirect coefficients. Various degrees of differences resulted between 1960 and 1980 in these coefficients as illustrated for the Lower Main Stem Subbasin (table 17).

The nature and magnitude of direct coefficients can be observed by reference to Lower Main Stem Subbasin for agriculture sectors (table 20). For virtually all sectors, direct coefficients differ for the three years--1960,1980, and 2010. In most instances, the changes from 1960 are increases; of special note is the projected increased use of chemicals (14) for crop production.

Range and feeder livestock are notable instances where coefficients decrease over the projections period. These decreases arise because (1) range livestock production is projected to remain relatively stable over the period, and (2) an increase in feeder livestock production will draw heavily on imports of both feed and livestock. The stable range livestock industry and forage production within the subbasin will not meet the projected needs of the feeder livestock industry.

Table 20.--Direct purchase per dollar of output, Lower Main Stem Subbasin, 1960, 1980, 2020

	Range livestock			Feeder livestock			Dairy		
	1960	1980	2010	1960	1980	2010	1960	1980	2010
1. Range livestock	.099888	.098	.095	.24873	.140	.108			
2. Feeder livestock	0								
3. Dairy	0						.021883	.020	.018
4. Forage, feed & food crops.........	.046722	.044	.041	.168035	.165	.161	.293639	.289	.282
5. Cotton..............	0								
6. Vegetables & melon products..........	0								
7. Citrus crops.........	0								
8. Forestry............	0								
9. Other agriculture....	0			.014048	.014	.013			
10. Uranium..............	0								
11. All other mining....	0								
12. Food & kindred prod.	0	0	.010				.152672	.158	.162
13. Lumber & wood prod...	0								
14. Chemicals..	0								
15. Printing & publishing	0								
16. Fabricated metals....	0								
17. Stone,clay & glass...	0								
18. All other mfg.	0	.006	0						
19. Wholesale trade......	.010286	.009	.008	.00864	.001	.001	.004580	.007	.009
20. Service stations.....	.010782	.011	.011	.003296	.003	.003	.009160	.011	.011
21. Eating & drinking places..............									
22. Other retail.........	.045359	.045	.045	.000324	.001	.002	.012214	.012	.011
23. Agric. services......	.015863	.018	.022	.067863	.070	.073	0	.014	.016
24. Lodging									
25. Other services.......				0	0	.001	.018321	.006	.007
26. Transportation	0	.014	.015	0	.025	.031	.027481	.031	.036
27. Electric energy......	.000372	.001	.002	.002918	.004	.005	.006107	.011	.017
28. Other utilities......	.000248	.001	.001				.001018	.003	.005
29. Contract construction									
30. Rentals & finance....	.006692	.010	.013	.002161	.005	.009	.011705	.018	.022

Table 20.--(continued)

Sector	Forage, feed and food crops			Cotton			Veg. & melons		
	1960	1980	2010	1960	1980	2010	1960	1980	2010
1. Range livestock ...									
2. Feeder livestock...							.000560	.001	.002
3. Dairy	.003267	.003	.003						
4. Forage, feed & food crops	0	.002	.004						
5. Cotton				0	.001	.002			
6. Vegetables & melon products							0	.001	.002
7. Citrus crops									
8. Forestry									
9. Other agriculture..									
10. Uranium									
11. All other mining...									
12. Food & kindred products									
13. Lumber & wood prod.									
14. Chemicals	.056252	.073	.099	.066772	.074	.079	.023982	.043	.069
15. Printing & pub. ...									
16. Fabricated metals..									
17. Stone, clay and glass									
18. All other mfg.									
19. Wholesale trade ...	.013776	.014	.014	.011906	.012	.012	.006477	.006	.006
20. Service stations ..	.023225	.022	.020	.012408	.012	.012	.004691	.007	.007
21. Eating & drinking places									
22. Other retail	.049011	.048	.046	.026178	.025	.023	.031369	.031	.031
23. Agric. services ...	.007330	.013	.019	.083196	.089	.092	.522214	.530	.535
24. Lodging									
25. Other services	0	.001	.002	0	.001	.002			
26. Transportation	0	.003	.004	0	.003	.004	.055386	.026	.026
27. Electric energy ...	0	.010	.015	.001865	.004	.006	0	.006	.009
28. Other utilities ...				.001219	.002	.003	0	.002	.002
29. Contract construction									
30. Rentals & finance..	.012981	.019	.024	.015205	.019	.023	.048034	.052	.056

Table 20.--(cont'd.)

Sector	Citrus crops			Forestry			Other agric.		
	1960	1980	2010	1960	1980	2010	1960	1980	2010
1. Range livestock ...									
2. Feeder livestock ..									
3. Dairy									
4. Forage, feed & food crops							.019360	.023	.028
5. Cotton									
6. Vegetables & melon products									
7. Citrus crops	0	.001	.001						
8. Forestry									
9. Other agriculture..							0	.002	.004
10. Uranium									
11. All other mining...	.012166	.015	.019						
12. Food & kindred prod.							.070427	.074	.078
13. Lumber & wood prod.									
14. Chemicals	.024036	.034	.039				.006098	.008	.013
15. Printing & pub. ...									
16. Fabricated metals..									
17. Stone, clay & glass									
18. All other mfg.							0	.001	.002
19. Wholesale trade ...	.003858	.009	.010	.007151	.008	.009	.014177	.003	.005
20. Service stations ..	.005935	.006	.007	.023169	.026	.029	.024085	.026	.029
21. Eating & drinking.. places									
22. Other retail	.015134	.015	.014	.010870	.011	.011	.041616	.042	.041
23. Agric. services ...	.626113	.630	.633				.046951	.053	.058
24. Lodging									
25. Other services	0	.001	.002	.068650	.001	.002	0	.001	.002
26. Transportation	0	.008	.011	0	.013	.016	0	.001	.001
27. Electric energy ...	0	.009	.013				.003354	.008	.011
28. Other utilities ...							.001524	.003	.005
29. Contract constr. ..									
30. Rentals & finance..	.004154	.009	.014	.050343	.056	.059	.024085	.028	.031

WATER QUANTITY CONSTRAINED PROJECTIONS 1980 AND 2010

While the agricultural projections, especially with reference to water development for supplemental and new land irrigation, were made within a general framework of water availability, the impact on water requirements of the large increases projected for nonagricultural sectors have not been recognized at this stage of the analysis. These increases are closely associated with projected population growth, especially for the Gila Subbasin.

Agricultural projections (unconstrained) also included major increases in crop production per acre. These larger yields would be due partly to improved varieties and large applications of fertilizers and other non-water yield improving practices. Improved efficiency in water use could also enlarge the effective water supply, although improved water use efficiency in an upstream area may mean less water for another area downstream.

In any event, estimates of the total impact of the above elements on water requirements was the next major stage in the analysis.

A concept of net water disappearance is highly important to this analysis. In effect, this magnitude is the difference between water diverted, applied, and used and the quantity returning to stream channels and groundwater supplies that becomes available for re-use. With respect to agricultural production, net water requirements or depletions comprise the usual consumptive use (evapotranspiration) plus disappearances that are not available for re-use within a relevant time period. Timing is important, especially with reference to groundwater supplies since, in some areas, lengthy time periods between surface application of water and return to the groundwater supply makes these supplies irrelevant to economic considerations.

Water Diversions and Applications[1/]

Quantities of water diverted for irrigation quite obviously exceed net depletions except in localized situations. This relationship occurs because irrigation systems and on-farm use of water usually achieve far less than 100 percent efficiency of use. This fact is highly important also in consideration of water needs for irrigation purposes. Two major magnitudes must be recognized and provided: (1) diversions, and (2) net depletions.

The above relationships have important implications also with respect to supply and quality of water. Return flows and re-use of water become highly significant variables. Thus, water can be and often is diverted and applied several times before it disappears completely. At the same time, in this process of return flow and re-use, the quality of the remaining water frequently deteriorates.

1/ FWPCA Staff at Denver, Colorado, contributed substantially to these estimates.

Diversions in 1960 and diversion needs for projected uses in 1980 and 2010 were estimated for each subbasin. Major data problems prevail such as lack of diversion measurements, excessive diversions in some systems, and the problem of appraising total quantities with respect to adequacy of seasonal distribution. Total diversions within a subbasin, for example, might exceed in quantity the total basic supply of water because of return flows and re-use.

In 1960, about 12 1/2 million acre feet of water, including re-use of return flows, were diverted[1/] from stream channels for agricultural use in the six subbasins (table 21). About 56 percent of the diversions were in the three lower subbasins. Projected diversions are about 13 1/2 million acre feet in 1980 and 13 1/4 million acre feet in 2010. The largest increases are in the upper subbasins; in fact, the lower subbasins, largely Gila, show a substantial projected decrease in diversions for agriculture in 2010.

Diversions per acre of irrigated land average around 4.75 acre feet for the total Colorado Basin. This average is comprised of a little over 4.0 acre feet in the upper subbasins and 5.5 acre feet in the lower subbasins.

Substantial losses of water occur in the distribution systems so that deliveries to farms average considerably less than these average diversions. However, exceptions occur. For example, nearly 8 acre feet were diverted per acre in 1960 in the Lower Main Stem and undoubtedly the farm deliveries were also high in this subbasin. In contrast, average diversions in Gila Subbasin were about 5.0 acre feet per acre in 1960; farm deliveries probably approached 5.0 acre feet in this subbasin because of the relatively large portion of total supply from groundwater sources.

Diversion quantities of water projected for 1980 show about the same relative increase over 1960 as projected acres in the total basin. However, by 2010, improved distribution and farm efficiencies reduce the diversion increase to 5 percent over 1960 versus an acreage increase of 10 percent over 1960.

Variability of water supply among years as well as within growing seasons is a major problem in the Colorado River Basin. The above single estimates tend to be "average" situations. Variations above or below will likely occur in a given year.

Net Water Depletions - Summary

Consistent and complete data for depletions of water are even more lacking than they are for diversions, return flows, and re-use. In the Lower Main Stem Subbasin, for example, aggregate measurements of diversions and return flows are available in most instances of irrigation water use. In contrast, these kinds of data are highly inadequate in the Green Subbasin. Overall, it was necessary to utilize several kinds

---

1/ Includes groundwater pumping.

Table 21.--Total diversions of water for agricultural use, by subbasins, 1960 and projected 1980 and 2010

Subbasin	1960	1980	2010
	Acre feet	Acre feet	Acre feet
Green	2,617,784	2,806,272	2,918,284
Upper Main Stem	2,312,737	2,666,199	3,174,149
San Juan	618,000	981,000	1,397,000
Total Upper Colorado ..	5,548,521	6,453,471	7,489,433
Per acre	4.06	4.17	4.20
Little Colorado	41,100	48,500	45,500
Gila	5,178,000 1/	5,328,000 2/	3,848,000 3/
Lower Main Stem	1,775,000	1,610,000	1,890,000
Total Lower Colorado...	6,994,100	6,986,500	5,783,500
Per acre	5.49	5.56	5.13
Total Colorado River Basin	12,542,621	13,439,971	13,272,933
Per acre	4.75	4.79	4.56

1/ 3,513,000 acre feet pumped from groundwater supply.
2/ 3,791,000 acre feet pumped from groundwater supply.
3/ 2,367,000 acre feet pumped from groundwater supply.

of information to estimate depletions, including water flow measurements, consumptive use estimates, efficiency of use estimates, and various assumptions.

Depletions are only partial indicators of adequacy of supply in terms of total quantity and distribution through the period of plant growth and other needs. In particular, where storage is lacking, excessive quantities of water frequently are applied because it is available in the streams, partly to compensate for other periods of water shortage. Although this practice may be logical from the standpoint of individual farmers, it likely results in depletions larger than would be necessary during these high runoff periods if supply could be controlled. Of course, the addition of storage facilities in a particular area alters supply and distribution both for this area and for areas downstream.

Estimates of water depletions were made for each livestock and crop sector for each subbasin I-O model. These results are discussed in the next section.

In 1960, water depletion in the Colorado River Basin was estimated at 8,711,381 acre feet (table 22). This quantity is not necessarily a 1960 calendar or water year depletion. While 1960 served as a base year, adjustments were made in the economic activity where it was evident that 1960 deviated substantially from a "usual" or somewhat "average" situation.

Table 22.--Depletions[1/] of water, total and agriculture, Upper and Colorado River Basins, 1960, 1980, 2010

Year	Total		Agriculture		Portion used by agriculture	
	Upper Basin	Lower Basin	Upper Basin	Lower Basin	Upper	Lower
	- - - - - - - - - Acre feet		- - - - - - - -		- - Percent - -	
1960....	2,187,181	6,524,200	2,116,515	6,302,062	97	97
1980....	2,748,036	6,539,799	2,652,939	5,927,377	97	91
2010....	3,211,139	6,876,125	3,074,732	5,420,625	96	79

1/ These quantities relate specifically to economic activity in the six subbasins. They do not include exports of water out of the Colorado River Basin or use of Colorado River water in the State of California. In the Green Subbasin, a substantial quantity of water in Bear River and Snake River drainages in western Wyoming counties is included because of the "representative" county approach.

Of total water depletions estimated for 1960, 97 percent were attributed to agriculture. This relationship held for both the upper and lower basins. About 75 percent of total basin depletions in 1960 were in the three lower subbasins (table 22).

Estimated depletions in 1980 for all uses in the basin are 9,287,835 acre feet in 1980 and 10,087,264 acre feet in 2010. Lower subbasins accounted for 70 and 68 percent, respectively. These decreases in agricultural use reflect increased irrigation development projected in the upper subbasins and curtailment of irrigation projected for the Gila Subbasin which were not offset by increased water needs projected for nonagricultural uses.

Projected total depletions for all uses for 1980 are 107 percent of 1960 and for 2010, 116 percent of 1960. In contrast, similar relationships are 126 percent and 146 percent for the upper subbasins and slightly more than 100 and 105 percent for the lower subbasins. Agricultural water depletions are projected in the upper subbasins to increase 45 percent over 1960 by 2010, while in the lower subbasins, agricultural depletions by 2010 are projected to decrease 14 percent from 1960 (table 22).

The portions of all water depletions chargeable to agriculture are 97, 97, and 96 percent in the upper subbasins for the 3 years. In the lower subbasins, similar percentages are 97, 91, and 79 (table 22). The substantially lower percentage in 2010 for lower subbasins results from a projected decreased irrigation economy in the Gila Subbasin.

Net Water Depletions - Subbasins and Sectors

Net depletions of water were estimated by sectors for each subbasin and year (tables 23-25). The Green Subbasin is an exception since all agriculture in this subbasin was analyzed as a single sector.

Two sectors--forage, feed, and food crops and cotton--are the largest net consumers of water among agricultural sectors. Cotton, of course, produces a large total gross output. Total water consumption by the food and kindred products and the lumber and wood sectors is relatively low.

During the course of the study, it proved impractical, and in some instances undesirable, to define agricultural sectors precisely the same among subbasins. The composition of production within sectors differed also, especially with reference to portions of irrigated and dryland crop production.

A major difference in definition of sectors prevails for range livestock and dairy. In the Upper Main Stem and San Juan Subbasins, substantial acreages of forage crops are included in these two livestock sectors which in turn reduces the magnitude of the forage, feed and

Table 23.--Depletions of water by agriculture, by subbasins, 1960

Sector	Green	Upper Main Stem	San Juan	Little Colorado	Gila	Lower Main Stem
	Acre feet					
Agriculture	811,877					
Range livestock..	(5,608)	693,188	373,983	2,376	7,787	1,808
Feeder livestock.		74		15	1,817	684
Dairy............	(457)	103,504	36,868	27	1,646	163
Forage, feed & food...........		40,214	11,596	33,399	2,638,708	583,209
Cotton...........					2,078,883	185,450
Vegetables & melons.........		1,955 1/			198,838	114,129
Citrus		24,849 2/	10,191 2/		83,889	82,168
Other agriculture		5,486	2,698	1,100	235,583	50,128
Agric.services...		29	3		157	98
Totals	811,877	869,299	435,339	36,917	5,247,308	1,017,837
Food & kindred...	38	182	47	9	1,285	229
Forestry.........	0	0	0	0	0	0
Lumber and wood	108	216	49	938	794	614
All sectors....	827,327	886,828	473,026	50,001	5,425,079	1,049,120

1/ Truck.
2/ Fruit.

Source: "Vol. III" of Report June 1968, App. Part II.

Table 24.--Depletions of water by agriculture, by subbasins, 1980

Sector	Green	Upper Main Stem	San Juan	Little Colorado	Gila	Lower Main Stem
	Acre feet					
Agriculture	992,473					
Range livestock..	(5,840)	806,242	527,013	3,135	10,551	1,798
Feeder livestock.		495		21	2,412	1,201
Dairy	(472)	81,616	94,967	51	4,355	313
Forage, feed & food		76,899	17,009	40,104	2,254,425	641,106
Cotton					1,965,615	243,156
Vegetables & melons		2,711 1/			132,698	166,612
Citrus		36,371 2/	10,067 2/		90,953	133,442
Other agric.		4,953	2,082	1,219	171,862	61,871
Ag services		38	3	--	211	266
Totals	992,473	1,009,325	651,141	44,530	4,633,082	1,249,765
Food & kindred...	32	224	56	12	2,349	498
Forestry	0	0	0	0	0	0
Lumber & wood ...	220	256	267	1,251	1,779	699
All sectors ...	1,011,437	1,041,914	694,685	74,719	5,114,799	1,350,281

1/ Truck.
2/ Fruit.

Table 25.--Depletions of water by agriculture, by subbasins, 2010

Sector	Green	Upper Main Stem	San Juan	Little Colorado	Gila	Lower Main Stem
	- - - - - - - - - - - - Acre feet					
Agriculture	1,029,252					
Range livestock...	(6,065)	985,593	637,404	3,530	13,814	1,860
Feeder livestock..		970	--	26	3,157	1,617
Dairy	(484)	91,615	165,759	87	9,191	385
Forage, feed & food		73,324	19,588	37,422	1,742,560	647,323
Cotton					1,814,771	262,554
Vegetables & melons		3,915 1/			110,073	294,770
Citrus		51,064 2/	10,919		110,963	203,445
Other agric.		3,800	1,470	1,326	69,099	91,967
Ag services		53	6		246	439
Totals	1,029,252	1,210,334	835,146	42,391	3,873,874	1,504,360
Food & kindred ...	29	215	66	13	2,346	688
Forestry	0	0	0	0	0	0
Lumber & wood	196	381	241	1,177	2,983	698
All sectors	1,056,014	1,265,763	889,362	91,256	5,053,865	1,731,004

1/ Truck.
2/ Fruit.

food sector. In the other subbasins, forage acreages and water depletions are included in the forage sector and water depletions for the livestock sectors are restricted to consumption by the animals. Thus, water depletions for range livestock and dairy sectors in the Lower Main Stem and San Juan are many times greater than for other subbasins even though livestock numbers and gross total output for these sectors are similar for all subbasins. In contrast, water depletions in these two subbasins for the forage sector are much less than for other subbasins, even though forage crop acres may be similar.

Production of dryland crops, mainly wheat and beans, is important in all or part of the upper subbasins, whereas dryland crops are relatively much less important in the lower subbasins. This situation reduces water depletions in the upper subbasins for the forage, feed and food sector relative to gross total output. Note is made of this matter also in the next section on water coefficients.

Water Coefficients

Water coefficients are expressed in terms of water depletions per unit of total gross output (dollars). Gallons per dollar output is used here for illustrative purposes (table 26).

Table 26.--Water coefficients (gallons depletion per dollar of output), agriculture sectors, by subbasins, 1960

Sector	Green	Upper Main Stem	San Juan	Little Colorado	Gila	Lower Main Stem
	gals/$ output					
Agriculture....	5,399					
Range livestock	--	7,986	8,048	76	75	73
Feeder "	--	6	--	9	7	12
Dairy	--	10,690	7,168	26	20	27
Forage, feed & food	--	2,262	1,075	8,950	23,108	16,782
Cotton	--	--	--	--	4,796	4,334
Vegetables & melons........	--	739 1/	--	--	1,339	1,302
Citrus	--	1,297	5,181 2/	--	4,027	7,945
Other agric. ..	--	672	1,043	1,342	8,204	2,490

1/ Truck crops.
2/ Fruit.

In 1960, coefficients for range livestock in the lower subbasins were about 75 gals/dollar output, for feeder livestock around 10 gals/dollar output, and for dairy products 20-25 gals/dollar output. Coefficients in the upper subbasins for range livestock and dairy sectors range from 8,000 to 10,000 gals/dollar output. This wide difference from the lower subbasins arises because these sectors in the upper subbasins include forage and feed crops.

Vegetables and melons in the Lower Colorado subbasins and fruit and truck crops in the Upper Main Stem had the lowest water depletions per dollar of output (about 1300 gallons) of any crop sectors in 1960 (table 26). Cotton used around 4,500 gallons per dollar output and citrus from 4,000 to 8,000 gallons.

Forage and feed crops are relatively high users of water per dollar of output (table 26). Coefficients for these crops were in the 10,000 to 20,000 gallon range per dollar output for the lower subbasins and around 2,000 gallons per dollar output for the upper subbasins. These differences between subbasins arise because of variations in relative importance of dryland crop production.

While not shown in this report, water coefficients projected for 1980 and 2010 generally are substantially lower than those prevailing in 1960. Improved water efficiencies, greater outputs per unit of land and livestock, and similar other improvements result in lower water coefficients.

For illustrative purposes, water depletions and water coefficients for nonagricultural sectors are reviewed for two subbasins--Gila and Lower Main Stem (table 27). The coefficients are only small percentages of coefficients in agriculture. Equally evident is the fact that total water depletions for nearly all sectors are extremely low; again, only about 3 percent of all water depletions in the Colorado River Basin are by nonagricultural sectors.

Major exceptions to the above are depletions for households and depletions for primary metals in Gila Subbasin. Households are the major net user of water by wide margins among nonagricultural sectors. Depletions for households are based on 27,335 gallons per capita population.

The tendency is to conclude that water should be transferred from agriculture to nonagriculture where water coefficients per dollar of output are so low. This argument may be somewhat pointless and is not especially useful since total water depletions in most nonagricultural sectors are a "drop in the bucket." These sectors will ordinarily be able to purchase the necessary water because water inputs are relatively insignificant in their total operations.

Table 27.--Water depletions and coefficients, selected[1] nonagricultural sectors, Lower Main Stem and Gila Subbasins, 1960

Sector	Lower Main Stem		Gila	
	Depletions	Coefficients	Depletions	Coefficients
	Acre-feet	Gals/$ output	Acre-feet	Gals/$ output
Primary metals.....	--	--	25,824	21.6
Chemicals	548	9.1	3,995	7.1
Stone, clay & glass............	498	10.7	1,216	11.4
Wholesale trade....	135	1.1	782	1.1
Eating & drinking..	141	1.3	470	1.3
Other retail.......	402	1.4	1,786	1.4
Lodging............	2,064	5.5	792	5.5
Other services.....	748	1.6	930	1.6
Transportation.....	222	1.5	458	1.5
Electric energy....	1,029	11.0	4,797	14.0
Other utilities....	71	0.7	494	1.0
Contract construction............	2,936	6.0	9,583	6.0
Rentals & finance..	119	0.4	370	0.4
Households.........	19,759	27,335.0[2]	97,259	27,335.0[2]
Government.........	873	1.6	4,001	1.6

1/ Those with larger TGO's or larger water users.
2/ Gallons per capita, annually.

Summary Effects

The conclusion was made from this study that quantities of water used at 1960 quality levels would not restrict the unconstrained projections of economic activity in any of the subbasins. However, it seemed apparent in the Lower Main Stem, for example, that all available water would be utilized under these projections by 2010.

Several points should be re-emphasized. The unconstrained agricultural projections of irrigated land were made within a general framework of projected water supplies. It is not especially surprising, then, that more detailed examination showed that water available would meet these projected economic activities, even with large increases in nonagricultural activity. In the Gila Subbasin, especially, the "unconstrained" agricultural projections, as noted earlier, included substantial curtailment of irrigated agriculture by 2010

WATER QUALITY CONSTRAINED PROJECTIONS 1980 AND 2010

Deterioration of the quality of water in the Colorado River Basin has been observed over a period of years. From the standpoint of agriculture, salinity is the major concern. Prospects are that water quality will deteriorate further with additional development and use of water in the Basin. In view of this general situation, Economic Research Service was requested by the contractor to conduct special studies of impacts of various levels of water quality on the agricultural economy of the Basin.1/

Application of poorer quality water on agricultural lands might (1) alter the cropping pattern, (2) reduce yields, (3) increase costs, and (4) increase water needs for leaching. The decisions hinge mainly, of course, on the most profitable alternatives, and on institutional and physical constraints with respect to the availability of additional water in water-short Colorado River Basin.

Empirical physical data are meager, especially with respect to on-farm experience. Initially, plans for this study were to collect data from farmers. A substantial amount of exploratory work was done. Local farm and business leaders were contacted. A small sample of farmers was interviewed in selected areas of Arizona. But, in the time available, situations that would permit establishment of the damages and costs associated with different levels of water quality could not be identified in actual experience. It appeared that farmers were, with the qualities of water being used, making management adjustments that offset or covered up identification of these impacts.

1/ This introductory section is from an article by Clyde E. Stewart and M. Glade Pincock, "Impacts of Water Quality on the Agricultural Industry of the Colorado River Basin - An Interindustry Study." Report No. 16. Conference Proceedings, Committee on Economics of Water Resources Development, WAERC, San Francisco. Dec. 12-13, 1967. pp. 115-135.

Efforts then shifted to use of experimental work, primarily that of U.S. Salinity Laboratory at Riverside, California. These results were supplemented by other research information and by informed judgments of scientists in the field of water quality. The Wellton-Mohawk Irrigation District in Yuma County, Arizona, was selected as a case study area.[1/]

Little economic analysis has been made of the effects of different levels of water quality on agricultural output and income. Numerous scientific treatises dealing with controlled experiments in hydrology, soil physics, and plant physiology have been published. Some of these results are pertinent to an economic evaluation. Experimental limitations are such that no one investigation has treated specifically of the elements that come to bear on the situation.

The investigation of the effects of water quality in agriculture was designed: (1) to develop methods and procedures to determine losses in output and income due to salinity of irrigation water, (2) to determine the magnitude of damages that might be expected in a specific irrigation project, (3) to appraise what, if any, adjustments might be required in the cropping pattern for specific areas, and (4) to evaluate direct effects of water quality on agriculture.

Budgeted Costs and Returns[2/]

Enterprise budgets for selected crops assumed the same direct variable input items in 1960, 1980 and 2010 and valued them at 1960 prices. The level of inputs for fertilizer, pesticides, insecticides and other chemicals, harvesting, and hauling were varied according to yield. For some crops, yield decrements were associated with salinity. Net salinity damage was defined as the gross value of production foregone, less the direct variable costs of producing and harvesting.

Farm budgets were developed for five crop rotations that were judged most likely to improve Wellton-Mohawk farm incomes.[3/] The most profitable rotation was alfalfa, cotton, and safflower. The least profitable rotation was cotton and alfalfa, with a large increase in acreage of alfalfa. Three rotations included barley, bermudagrass seed or wheat along with cotton and alfalfa.

1/ This study is reported in detail in a report by M. Glade Pincock, "Economics of Water Quality in Agriculture - A Case Study, Wellton-Mohawk Irrigation District, Yuma County, Arizona, 1960, 1980, 2010." USDA-ERS. Salt Lake City. July 1967. Processed. 81 pp.

2/ Stewart and Pincock, op cit.

3/ Luke B. Wishart and A. G. Nelson, "Farm Adjustment Possibilities to Increase Income in the Wellton-Mohawk District of Yuma County." Arizona Agr. Expt. Sta. Report No. 218. Oct. 1963.

Large acreages and high incomes for specific crops are not consistently related in practice. For 1960, 1980 and 2010 cotton ranked in the top three crops for both acreage and for net income over direct variable costs. Alfalfa consistently ranked number one in acreage, but ranked 9, 9, and 10 in terms of income. Oranges ranked first or second for income but ranked 11, 4, and 3 in terms of acres.

Findings of this study showed no basis for adjusting cropping pattern projections because of water quality deterioration. Net increments in yields from improved practices were projected for the period 1960 to 2010 above salinity damages resulting from projected degradation of water quality.

One measure of the effect of the use of lower water quality on agriculture is a reduction in gross value of production. The reduction was obtained by applying 1960 prices to the difference between unconstrained yield using 1960 quality irrigation water in the target years and the constrained yield using projected lower quality irrigation water in the target years.

Projected Levels of Water Quality

This interindustry input-output study was completed before the Federal Water Pollution Control Administration (FWPCA) had finished its investigations and projections of water quality and associated damages. In order to develop and test I-O techniques in the appraisal of direct and indirect effects of deteriorated water quality, earlier studies and projections of water quality were utilized along with the special FWPCA studies to the extent they were available.

Studies and reviews[1/] indicated that the level of resource development associated with the economies projected for the input-output study would not significantly affect quality of water and impacts of deteriorated water quality on economic activity by 1980 or 2010, except in the Lower Main Stem and Gila Subbasins. On the basis of the special study in the Wellton-Mohawk area and of other investigations and research, preliminary estimates were made of economic impacts on all segments of the economies in these two subbasins.

Water quality levels utilized as a basis for estimating damages and quality constrained projections are:

1/ Primarily by Federal Water Pollution Control Administration perseonnel at Denver, Colorado.

Year	Lower Main Stem Area A[1]	Area B[2]	Area C[3]	Gila
	- - - - - - - - - -	ppm	- - - - - - - - - -	-
1960	700	900	1,242	650
1980	800	1,000	1,242	690
2010	1,100	1,200	1,690	700

1/ Colorado River Indian Reservation, diversion point at Headgate Rock Dam.

2/ Remainder of Yuma County, Arizona.

3/ Clark and Lincoln Counties, Nevada; Washington County, Utah; and Mohave and Coconino Counties, Arizona.

The above projected magnitudes of water quality levels are based on earlier surveys and published and unpublished reports. They should be viewed as preliminary pending results of more detailed investigations in process or planned. They are, then, subject to change and were utilized in order that this stage of the input-output study could be brought to completion from the standpoint of methodology. The estimates appear to be realistic given the assumptions and projections of economic activity for the study area. The estimated quality levels also served reasonably well the needs from a procedural standpoint with respect to I-O techniques.

A likely further limitation with respect to the above water quality levels is the fact that they were estimated independently of the economic activity projected in the present study. Subsequent analysis by FWPCA will recognize the current projections of subbasin economies, as well as utilize more detailed surveys of water quality levels and impacts.

Measurement of Damages from Water Quality Deterioration[1]

The quality constrained projections presented the most difficult problems in this study. Initially an estimate is made of the increased salinity concentration in river water resulting from the projected higher levels of economic activity in each subbasin. The major contribution to total dissolved solids will likely come from increased water applications in agriculture. A basic assumption is that TGO of each sector in the target years will depend upon the availability of an adequate water supply of a specified quality, as well as upon the demand for that sector's output. Thus, the quality-constrained projections are not complete until a level and structure of economic activity for each subbasin are estimated where the accompanying water requirements--both quantitative and qualitative--are met.

The economic effects of a change (degradation) in water quality

1/ Details of preliminary procedures are shown in the nine-volume report referenced earlier. Vol. I, pp. 198-201.

can be shown through the use of the input-output model by making three adjustments: (1) change direct coefficients, where appropriate, to reflect changing costs; (2) adjust final demand to account for changes in household demand; and (3) adjust final demand to reflect direct changes in output.

Damages from Deteriorated Quality

A summary of agricultural damages estimated for 1980 and 2010 for Lower Main Stem and Gila Subbasins is shown in table 28. The input-output technique and models were utilized in arriving at these estimates.

The greatest agricultural damages (decreases in TGO) are projected in the Lower Main Stem because of projected large changes in water quality. Industrial costs or damages from increased water treatment and increased water purchases in this preliminary test run were reasonably moderate though substantial. Household damages or costs (purchases of soap) loomed very large in the Gila Subbasin. These latter costs are a function of large population numbers and growth along with a moderate decline in water quality.

Estimated total gross output with water quality constraints, compared with unconstrained projections and base year 1960, show annual direct determinants from deteriorated water quality. The 1960 outputs and unconstrained projections already have imposed on them the effects of deteriorated water qualities that prevailed in 1960. Thus, comparisons for Lower Main Stem and Gila Subbasins are not between high quality water and projected quality in 1980 and 2010, but from a 1960 base quality ranging from 650 ppm in Gila to 1242 ppm in Area C of Lower Main Stem.

Total gross output is projected to decrease for all crop sectors in these two subbasins if water quality deteriorates as shown above. Vegetables and melons, citrus, and cotton show the largest relative and absolute declines in the Lower Main Stem Subbasin (table 16). These sectors are affected most also in Gila Subbasin but projected water quality changes and damages are substantially less in this subbasin.

The technical note in the nine-volume report referred to earlier gives further insight into the nature of these damages as well as procedures relative to the I-O technique. For agriculture, the estimates of depression of total gross output are the direct detriments to agriculture from assumed water quality deterioration. These direct detriments through the final demand route and I-O mechanics provide an estimate of indirect damages or effects throughout a subbasin economy because of these lower total gross outputs.

In 2010, direct damages to Gila Subbasin agriculture amounted to about $442,000 per year and indirect damages were about half as large

Table 28.--Estimated changes in total gross output for all agricultural sectors under illustrative levels of water quality constraints, Gila and Lower Main Stem Subbasins, 1980 and 2010

Projection	Total gross outputs	
	Gila Subbasin	Lower Main Stem Subbasin
	000 dollars	000 dollars
Unconstrained (1960 quality)		
1960................	391,078	95,864
1980................	617,649	198,638
2010................	840,071	304,560
Quality constrained		
1980................	617,324	198,181
2010................	839,629	301,459
Change in GTO from quality constraint		
1980................	325	457
2010................	442	3,101

See table 16 for details.

as direct. Total damages in the Lower Main Stem Subbasin were estimated at about $5,500,000 per year of which $3,100,000 or about 55 percent of the total is direct damages.

While agricultural damages are defined as decreased total gross output, these values are largely changes in net incomes. The changes in agricultural sectors are intended to be strictly yield decrements, and in turn, the income effects are net incomes except for costs associated with handling the different volumes of physical output.

INPUT-OUTPUT MODELS AND BENEFIT-COST ANALYSES

The adequacy of the input-output technique for small area studies and projections has been debated and argued extensively. A major merit appears to be its ability to consider simultaneously all elements of the economic activity of an area. Another major characteristic is its orientation to total gross output (income) magnitudes and changes; the merits of this characteristic depend on the measurement criteria of interest.

Whether TGO is a suitable measure for appraising benefits and costs related to water resources is a debatable point. This criteria apparently differs from benefit and cost criteria in U.S. Senate Document 97 which is the guide for resources development involving the Federal government.

The direct and indirect effects and coefficients in input-output models are not necessarily defined the same as direct and indirect benefits and costs in SD-97 and current benefit-cost analysis by Federal departments. The direct and indirect effects in the input-output model are total effects throughout the sector or industry, or throughout the total economy described by the model. These effects are not net effects or value of water, but effects and values of a much larger collection of inputs and activities. Of course, secondary effects as defined by some Federal agencies are of a similar gross nature also.

Among "Types of primary benefits and standards," Senate Document 97 includes:

> 3. Water quality control benefits: The net contribution to public health, safety, economy, and effectiveness in use and enjoyment of water for all purposes which are subject to detriment or betterment by virtue of change in water quality. The net contribution may be evaluated in terms of avoidance of adverse effects which would accrue in the absence of water quality control, including such damages and restrictions as preclusion of economic activities, corrosion of fixed and floating plant, loss of downgrading recreational opportunities, increased

> municipal and industrial water treatment costs, loss of industrial and agricultural production, impairment of health and welfare, damage to fish and wildlife, siltation, salinity intrusion, and degradation of the esthetics of enjoyment of unpolluted surface waters, or conversely, in terms of the advantageous effects of water quality control with respect to such items. Effects such as these may be composited roughly into tangible and intangible categories, and used to evaluate water quality control activities. In situations where no adequate means can be devised to evaluate directly the economic effects of water quality improvement, the cost of achieving the same results by the most likely alternative may be used as an approximation of value. 1/

Possibly the above statement is subject to interpretation. But "net contribution" is used and emphasized in the statement.

In the use of the model for damage estimates, certain basic estimates are first made outside the model. These initial estimates relate to impacts of quality changes on total gross output or costs. The primary estimates are change in total gross output, final demand, costs, and direct coefficients; the needed estimates depend on the kind of damages. After estimating these magnitudes, a new transactions table evolves and a new set of direct and indirect coefficients. The model then estimates impacts throughout the economy including indirect damages.

At this stage of the Colorado Economic Base Study, it is recognized that the direct damages shown for agriculture due to projected degradation of water quality are total gross output values or depressions of gross income (table 28). However, these decreases in agricultural TGO are net effects to a large extent. Direct damages shown for industries and households are basically additional costs and appear to be more completely on the order of "net" amounts. All indirect damages are total effects throughout the respective economies rather than net effects attributable to water.

Proponents of a single national efficiency criterion have maintained a continuing argument with those who contend that regional, local and other goals should also be considered in decision making at the national level. The "efficiency" group seems to have been losing ground in this argument as reflected by Federal and state policy with respect to natural resources development. Illustrative of this trend is a recent statement, presumably a possible supplement to SD-97, prepared by a Task Force of the Federal Water Resources Council. This

---

1/ U.S. Senate. Policies, Standards, and Procedures in the Formulation, evaluation, and Review of Plans for Use and Development of Water and Related Land Resources. Doc. No. 97. USGPO. May 1962. p. 9.

Task Force poses four coordinate national objectives for water resource development--national income, regional development, environmental enhancement, and well-being of people.

Whether these four new objectives are coordinate is subject to question; the set seem to include both means and ends. Even so, if this proposal is adapted by the Federal Government and accepted by states and others, the status of input-output analysis for evaluations and appraisals of resources development may be enhanced. At least conceptually, this technique seems to fit at least reasonably well the needs as defined by the Task Force for analysis of national income and regional development objectives. Practically, of course, this technique is demanding with respect to data requirements and research costs. The need for improved analytical techniques is so great, however, that the additional costs may not be unreasonable.